METALLURGIA

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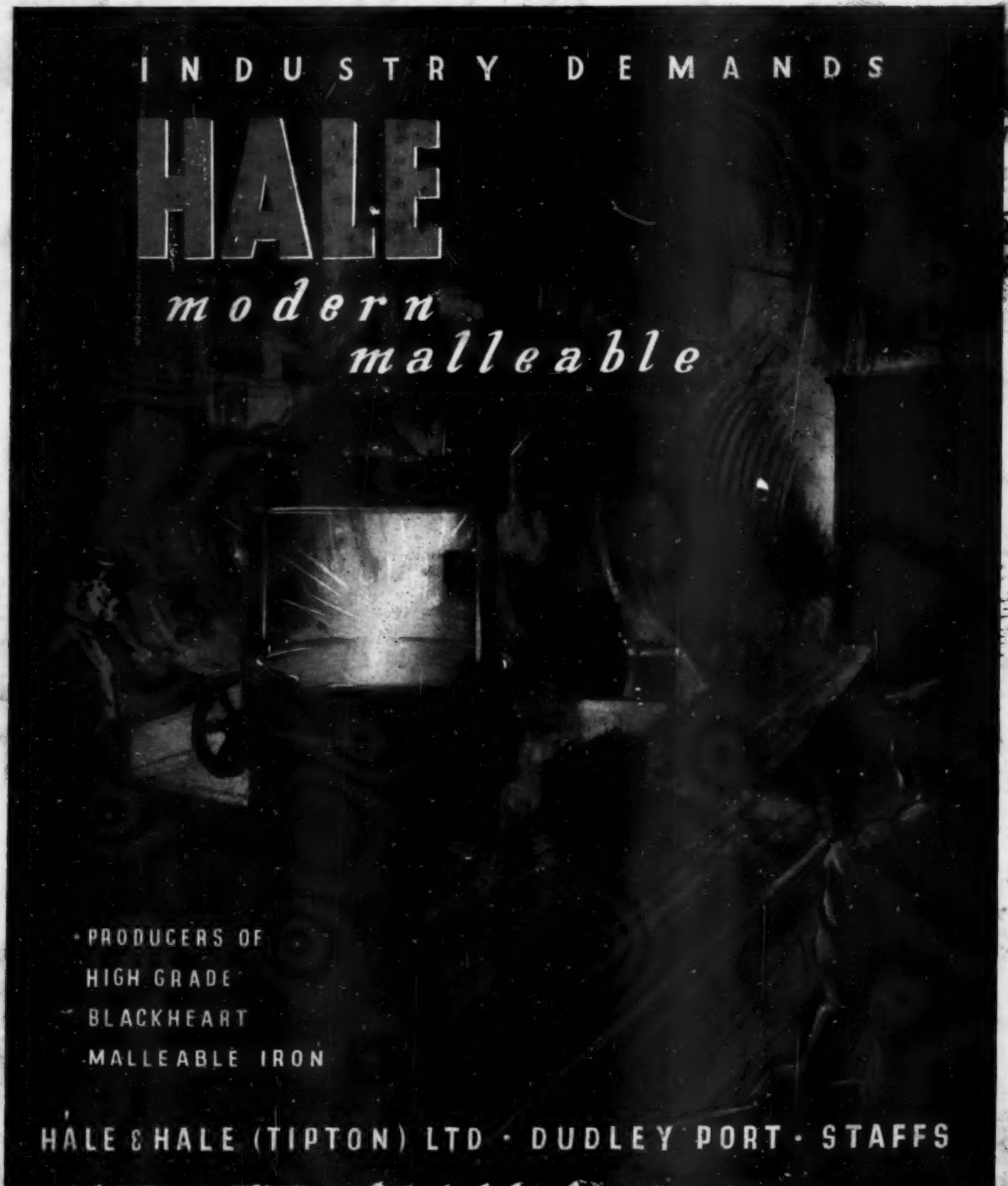

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INCORPORATING THE "METALLURGICAL ENGINEER."

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Productivity and Planning

THE Iron and Steel Productivity Team, whose Report* on last year's visit to the United States has just been published, had one important advantage over most of the other teams which have crossed the Atlantic. Apart from any changes which may have taken place as a result of nationalisation, it is probably true to say that in no other industry are the individual firms so closely integrated without losing their identity. For many years now, the British Iron and Steel Federation has been responsible for overall planning, and the free and full exchange of information within the industry has resulted in a state of affairs where managers and technicians have a good knowledge of the progress made in the industry as a whole, and in firms other than their own—a good foundation on which to represent the industry on a visit to America. Furthermore, the team was concerned only with the production of pig iron for steelmaking, and of open hearth steel and its subsequent fabrication into heavy rolled products (heavy bars and sections, rails, plates and billets); this reduced the number of firms to be considered in this country to a relatively small number—at least when compared with, say, the 2,000 ironfoundries who had a stake in the Ironfoundry Productivity Report. Accordingly, the team arrived in the United States not only well informed on the progress made in the last few years in the British industry, and on the present position here, but also with more than an inkling of possible future developments.

At a Press conference, held at the Federation's London headquarters to discuss the Report, the leader of the team, Sir Charles Goodeve pointed out that it differs from the reports of other industries in a number of ways. In the first place, it gives an even more careful analysis of the British Industry than of that of the United States. Secondly, it attempts to put the measurement of productivity on a more quantitative basis than hitherto; not only labour productivity but also other factors of production have been subjected to definition and measurement. Most important of all, it is related to the industry's Second Development Plan, details of which are expected before the end of the year.

The First Development Plan, it may be recalled, was approved in its general lines by the Government and published as a White Paper in 1946. In essence it was a plan to continue the modernisation of the industry and to raise steel production from 13 to 16 million ingot tons a year. This necessitated an expansion of pig iron production from 8 million tons in 1946 to an annual rate of 10·5 million tons. Both these increases have now been achieved.

The new five-year Plan is being formulated on the basis of increasing steel production to at least 20 million ingot tons a year, and pig iron production to 15 million tons a year. Such developments are bound to give rise to a number of problems associated with varied facets of the plan. First and foremost are those concerning raw material supplies. Increased amounts of ore and coke will be required to utilise the increased blast furnace capacity, and this matter has been under active consideration for some time. New sources of ore supply, particularly in Africa, are being explored and developed, and the National Coal Board is examining the problem of increasing the industry's coking coal supplies by 7 million tons a year over the present level.

Extensive capital investment will be necessary in coke ovens, blast furnaces, open hearth furnaces, rolling mills, and many other components of a modern steelworks. Moreover, special ore carriers are being built to help bring the large tonnage of imported ore to this country. These things are necessary if the steel is to be produced at all, but in their provision the question of productivity will have to be considered. The cost of making iron and steel in Britain remains low by international standards, but it can only be kept so by continuous modernisation and the most effective utilisation of plant. Capital development since the war, together with increased use of fuel oil and the introduction of the continuous working week, has already given an increase of 25% in the output of finished steel per man. Productivity, whether on a basis of plant or labour, is still less than in the United States, however, and although the better American raw materials, fuels, etc., are not without effect, the main factors which call for consideration in the light of the Report are the size of works and the size of individual items of plant.

As the Report sets standards of size, it will be of great value in assessing the practical possibilities of development in the context of British conditions and aiming at a minimum overall cost when all other factors—transport, fuel, raw material and capital costs—as well as labour productivity are taken into account. There is, of course, a close relationship between the size of the unit of plant and the size of the works, and because of this the efficiency of any integrated steelworks making bulk steel by the hot metal process increases steadily as it grows to a capacity of between 750,000 and a million ingot tons a year; beyond that figure the gain is small. It follows that if the total annual output is set at 20 million tons a year, it will not be possible to achieve maximum efficiency by expansion in all the 40 works producing bulk steel. It will be necessary, therefore, for development and re-equipment to be concentrated in the works most suitably sited for expansion.

This process is already under way, and is endorsed by the team in the belief that it is essential for raising productivity and increasing efficiency. It will present many human problems, as must any change; but it is better to anticipate these problems rather than wait for the economic death of the inefficient firms, coupled with a delay in the growth of the industry's efficiency.

* Published by the Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1. Price 5s.

Fuel and Metals

Edward Williams' Lecture

THE importance of coke to the foundryman was emphasised by Professor R. J. Sarjant, O.B.E., in the Edward Williams' Lecture he delivered on the above subject at the Annual General Meeting of the Institute of British Foundrymen recently held in Buxton. The requirements of the foundryman's metal-melting practice demand specific properties in the fuel used. Ideally, it must be capable of producing the highest practicable temperatures, and there must be uniformity of performance. In addition, there are metallurgical requirements as to temperature of casting and chemical and physical properties of the metal produced, which are of prime importance. Other essential criteria of efficient practice are a required rate of output determined by the temperature levels operating, and economy of materials, which is dependent on both plant and process.

In considering the characteristics of the coke demanded for its satisfactory service in the cupola, Professor Sarjant said that there is an equivalence of requirement in the need, in both the cupola and the blast-furnace, for a specific property called " hardness " with the absence of fissuring, and stress, too, upon the importance of uniformity of size and quality. In the combustion of coke, the reactivity with oxygen is an important criterion in the determination of the operative temperature of the fuel bed. In both processes there enters, in varying degrees, the reactivity of the coke to carbon dioxide, since the product of this reaction, carbon monoxide, may lead to loss of potential heat in the effluent gases. In the blast furnace, these factors may not be of equal significance for two reasons ; in the first place, the temperature of the melting zone may be above the temperature at which the coke may be able to burn to carbon dioxide, and secondly, the carbon monoxide produced is an essential element in the major function of the furnace, namely, the reduction of iron ore.

Coals for the production of the best metallurgical coke are being gradually depleted and modern research is being directed towards bringing into service the less effective coking coals, it is a welcome sign, therefore, that the manufacturer of coke and the foundryman are collaborating in works' scale investigations into the assessment of the pertinent factors of cupola operation and the determination of the properties which are really required in a good foundry coke. It is necessary to be able to specify the essential properties in the coke for the guidance of the coke manufacturer. The trouble is that no satisfactory foundry coke specification has yet been found. The difficulties do not lie in any inability to sample the coke and apply to it a whole series of detailed tests ; many such tests have been developed. The problem lies rather in the determination of the required combination of properties and the significance to be applied to the inter-relation of the individual tests. As far as may be evident at present, the critical requirements for a foundry coke are : uniform size ; high strength and hardness ; low reactivity ; and low ash and sulphur. It is Professor Sarjant's view that the importance of reactivity has been under-estimated and, at the University of Sheffield, attention has been particularly drawn to this subject in a wider programme of research.

Many factors associated with the coal are contributory in determining the properties of the resultant coke. Thus there are the well-known chemical factors, composition, the nature of the banded constituents and the mineral impurities, physical factors such as the size of the coking slack, specific-surface, friability, bulk-density, plastic and swelling properties and pressure development on heating. Again, weathered coal is useless for coke manufacture. The coke-oven manager has his problems in the oven conditions, in the uniformity of heating, the nature of the time/temperature cycle during carbonisation and the multitude of mysterious changes going on inside the oven.

In the course of his lecture, Professor Sarjant discussed the work being done in correlating carbonising conditions and coke properties and in applying the results of work carried out by other workers in the field. Reference is made to reactions in the cupola and useful deductions are made from blast-furnace practice. Flow factors in the cupola are considered, and particular attention is given to coke reactivity and to the influence of gas velocity on reactivity as a result of some work in this field, from the conclusions of which it appears that the disability of a high reactivity can be compensated in some measure by an increase in any condition that may serve to add preheat or reduce endothermic demand in the metallurgical reactions ; humidity causes a reduction of carbon with the evolution of carbon monoxide and hydrogen. An increase of moisture content of the air can reduce both the tapping temperature and the melting rate. The use of hot-blast should produce conditions which counteract the adverse effect of inferior fuels but it introduces complications ; other possibilities for future development include the use of oxygen enrichment, but cheap oxygen is not yet available.

The concluding part of the lecture was concerned with a brief account of the impact of certain inquiries in the domain of furnace technology on the use in the foundry of fuels other than coke. Of these mention is made of an investigation into the variable flow of heat in metal and refractory masses ; heating effects of coal flames and smoke abatement ; gas-fired furnaces ; and a number of minor matters that enter into the fuel problems of the foundry.

One purpose of this lecture, as Professor Sarjant emphasised, was to seek out the fundamental issues upon which the eternal verities of good practice are based, and to invoke the spirit of science in a field that is perhaps as full of intricate technical problems as other more glamorous aspects of industrial activity.

British Standards Year Book

THE 1952 edition of this most valuable reference work has just been published. It contains a complete list of the 1,800 British Standards current at 31st March, 1952, with a brief description of the subject matter of each. A subject index simplifies reference. The price is 7s. 6d.

The Year Book also gives particulars of the membership of the General Council and of the Institution's Divisional Councils and Industry Standards Committees. These Industry Standards Committees, 59 in number, each represent a major British industry through whom the work of drafting British Standards is delegated to some 2,200 Technical Committees and Sub-Committees. In addition 20 Special Committees, some of an advisory category, are also listed.

The New Babcock and Wilcox Research Station

THE impressive main entrance hall of the new Babcock and Wilcox Research Station, with its hanging staircase, is somewhat reminiscent, architecturally, of the Festival of Britain's South Bank site, but crossing the threshold into the laboratories themselves soon dispels any illusion of an exhibition, for whilst the laboratories are well laid out, and equipped with efficient modern apparatus, it is quite evident that the emphasis is on work rather than show.

Growth of the Department

Throughout the Company's long history, research into the manufacture and operation of steam-raising plant has played an important part in the progress which has been made in the use of ever increasing temperatures and pressures. Up to about fifteen years ago, however, Babcock research was not consolidated as a central unit. For many years a mechanical test house and a chemical laboratory had existed as separate entities, their work being supplemented by independent investigation, carried out by individual departments on problems relating to their own particular interests, much of this research being on a purely *ad hoc* basis. In 1936, this independent experimental and research work was coordinated into the Research Department, divided into Mechanical, Metallurgical and Fuel Sections, located in well-equipped laboratories in the Renfrew Works. Since then, the scope and activities of the Research Department have expanded considerably and its physical dimensions have followed suit. As Renfrew Works was itself expanding, new premises seemed to offer the best solution, and the present premises were acquired shortly after the war and first occupied during 1950.

Located in High Street, Renfrew, about 1¼ miles from the Main Works, the Research Station occupies a site with a frontage of 285 yards and an area of 5¼ acres. The main block is a two-storey building with a floor area of 22,000 sq. ft., and behind it is a combustion research building with a floor area of 5,000 sq. ft. Further single storey buildings with a total floor area of 22,000 sq. ft. are being built as extensions to the laboratories, and these will house the hot rupture testing machines, electronics laboratory and other activities still carried on at the Main Works, together with pot furnaces and scaling test apparatus at present housed on the new site in an old golf club house which will be demolished when the new buildings are completed.

Eventually, all research activities will be accommodated at the Research Station, with the exception of full-scale boiler research which is carried out at the Works, so that the steam generated can be usefully employed. This research is carried out on a boiler with a capacity of 40,000 lb./hr. at a pressure of 1,500 lb./sq. in., and two other 450 lb./sq. in. boilers with capacities of 40,000 and 60,000 lb./hr. are available for special work when required.

The total number of persons employed in the Department is 205, and in addition to General Administration, there are six sections—Chemical, Fuel Testing, Mechanical Testing, Combustion Research, Engineering Research and Metallurgical—each under the control of a section leader. As it is impossible to deal adequately with all the sections in the space available, we shall pay particular reference to those aspects of the work most likely to be of interest to our readers.

Metallurgical Section

As in most metallurgical laboratories associated with engineering works, the activities of this section can be classified into three main categories: (*a*) routine examinations; (*b*) investigations of service troubles; and (*c*) research and development.

Routine Examinations—The bulk of the routine work comprises the macroscopic and microscopic examination of sections from the test plates employed for acceptance of welded pressure vessels, and control of works metallurgical processes such as case-hardening. The volume of work of the former category is sufficiently great to need the development of mass-production methods for specimen preparation and photographic recording.

In addition to the normal mechanised equipment for grinding and polishing specimens, the section is equipped with an electrolytic polishing unit in which the bath temperature is automatically controlled, in order to eliminate risks with solutions containing perchloric acid. In many cases, particularly where an examination of

Vickers projection microscope.

scale is desired, the edge of the specimen has to be preserved, and a solution has been developed whereby iron plating may be carried out in the cold.

For examination and photo-micrography of specimens, Vickers and Reichert projection microscopes and a Leitz Metallograph are available, the last two being fitted for automatic recording of numbers on the negative. The Vickers microscope has been equipped with a light intensity meter developed in the department, which allows a constant negative density to be obtained. Further developments are in train towards shutter operation by a light integrator, giving automatic control of exposure.

The importance of the camera as a recording instrument in investigation work, particularly on service troubles, is frequently underestimated, but such an accusation could not be levelled at the Babcock Research Station, for the photographic department is particularly well-equipped for all types of photography including laboratory, studio, outside and 16 mm. cine work, and the dark rooms and processing equipment can easily deal with 1,000 prints a week and the processing of some 200 micrographs per week in addition to 40–50 general photographs. Other work regularly carried out includes lantern slide and cine film and filmstrip processing, microcopying, Agfacolour, reflex printing, photo-engraving on aluminium, and the engraving of picture plates for the department's "Multilith" offset litho machine.

Investigation of Service Troubles—In accordance with the Company's policy, close collaboration is maintained with the Service Department, in order to provide advice and guidance on any trouble that may arise in clients' plant. The troubles investigated are very varied and a wide range of modern equipment is necessary to deal with them. Occasionally, troubles new to the section's experience arise, due in part to the general trend towards higher pressure and temperature steam plant, with its associated material and construction problems. In such cases, it may be necessary to initiate a comprehensive investigation.

Research and Development—In addition to research suggested by service investigations, programmes of a more long-term nature are undertaken. These are mainly concerned with the complex behaviour of materials at elevated temperatures, and the development of materials suitable for anticipated future requirements. Investigation of the properties of such materials include stress-carrying capacity, scale resistance and general microstructural stability.

Apart from micro-examination, structural stability may be investigated by measuring the changes in magnetic susceptibility, impact strength and resistivity. The first is measured by means of a ferrometer, while the impact strength is measured by conventional Izod tests, with the necessary modifications for tests on hot specimens. Change in resistivity is measured by conventional voltage-drop measurements and, since the change in resistivity is influenced by the degree of spheroidisation of the carbides in a specimen, a measure is obtained of the stabilising influence of carbide-forming elements such as chromium.

Progressively higher operating temperatures are calling for the use of austenitic heat resisting steels for certain parts of boiler plant, and one of the problems which this development introduces is that of joining austenitic and

Spectrographic analysis in the chemical laboratory.

ferritic parts, with their widely differing coefficients of thermal expansion.

Although the general emphasis of research is directed towards high-temperature properties, other features are also considered. Extensive work has been carried out on the minimum amounts of residual elements known to influence the hot-working properties of steel and a paper on the influence of copper, tin and nickel was published in our May issue. Facilities are available for carrying out Jominy hardenability tests, and investigations of heat treatment procedures such as austempering and martempering have been made, in order to improve still further the quality of tools, such as those used for tube-expanding, and an extensive range of heat treatment furnaces and quenching baths is available for this work.

Chemical Section

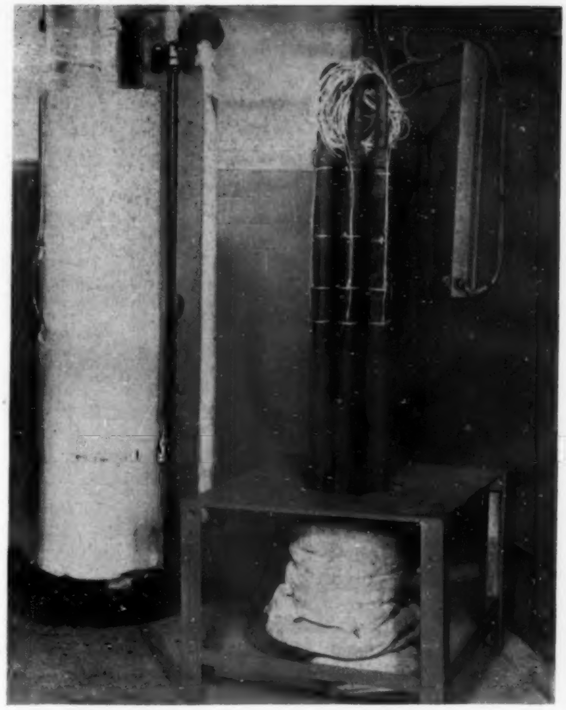
The Chemical Section is responsible for quality control of all material entering the works, control of pickling procedure, corrosion and surface protection problems, and certain aspects of the behaviour of metals at high temperatures. Routine analysis alone involves the examination of some 10,000 specimens which, with an average of four elements per sample, and duplicate testing, involves 80,000 determinations a year.

Methods of Analysis—It is not surprising, therefore, that extensive use is made of spectrographic and absorptiometric methods of analysis. A large Hilger quartz spectrograph is available for steel analysis and a medium quartz model for non-ferrous materials. A high-tension spark is made between a silver electrode and the specimen under test and the spectrum may be compared with the spectra of pure elements, for qualitative work, while for quantitative analysis, the densities of the lines are measured photo-electrically. Four Hilger Spekker absorptiometers (3 different models) are available for colorimetric analysis. Miscellaneous analyses, which may amount to 20,000 determinations a year, require procedures which vary as widely as do the specimens themselves, and new, improved and more rapid methods are constantly being investigated, resin separation methods being at present under review.

Corrosion Protection—The protection of metal surfaces against corrosion during transit and under service conditions presents a major problem. Developments in the production of protective coatings are constantly under review, materials being subject to heat and acid-resisting tests which have been specially standardised in the laboratory. Those materials considered to be superior to products currently in use, are recommended for trial under service conditions.

High Temperature Scaling—One of the principal material features on which information is required is the scaling behaviour of metals at elevated temperatures, and experiments in progress are designed to permit results, when taken in conjunction with other aspects of the investigation, to be extrapolated to some 100,000 hours' service conditions. The test specimens consist of tubular sections, machined from solid bars of the materials being investigated, suspended in the centre of an electric furnace, flue gas being supplied by a gas burner, with provision for injecting other gases as required. The furnaces, which are electrically heated and can be controlled to $\pm \frac{1}{2}°$ C. without flue gas, are arranged in two groups of six, each group having a travelling balance so that specimens can be weighed periodically without removal from the furnace. The fullest provision is made for continuous measurement of the furnace temperatures and for indicating and recording the CO_2 content of the flue gases.

Bank of six furnaces for scaling tests, showing instrument panel and traversing balance.



Steam rupture test for superheater tubes.

Mechanical Testing Section

Routine Testing—This aspect of the section's work is mainly concerned with quality control of materials and customers' acceptance tests. The equipment includes a Denison 30-ton single-lever tensile testing machine, an Avery 100-ton universal testing machine and an Izod impact testing machine, together with Brinell and Rockwell hardness testing machines. Adjacent to the routine testing laboratory is a well-equipped machine shop, which is available for the whole of the department's requirements, and a range of furnaces for carrying out heat treatment operations.

Elasticity Modulus Determination—Other testing machines are located in the investigational laboratory, a particularly interesting one being for the determination of the modulus of elasticity of small metal specimens by the electronic measurement of resonant frequencies. One of two glass silk loops suspending horizontally the rod specimen under test is attached to a loud-speaker diaphragm, and the other to a gramophone pick-up. The diaphragm is made to vibrate over a range of frequencies, and the rod begins to resonate when the appropriate frequency is reached. The resonance is detected by vibration of the pick-up which gives a signal on a cathode ray oscillograph. From the determined frequency of resonance, Young's Modulus can be readily calculated.

Hot Rupture Testing—In boiler plant, it is more important to know the length of time for which a material can sustain without fracture a given load at a

Welds tested to failure by cyclic stress reversal.

given temperature than it is to know the creep rate under a given set of conditions. Accordingly, greater attention is paid to hot-rupture testing in which samples of a material are submitted to a range of tensile stresses at elevated temperatures until failure occurs—which may take anything from a few hours to several months. There are two groups of 36 units each, electrically heated and thermostatically controlled to within 2° C., at the Renfrew Works.

Steam Rupture Testing—Steam rupture tests are also carried out on actual samples of superheater tubes. There are three machines, each capable of containing six specimens, which are fed with steam from an autoclave at pressures up to 2,000 lb./sq. in., and any temperature required, until they burst. To minimise the accumulation of hydrogen inside the tubes, heated palladium discs are provided which allow the hydrogen to leak off to atmosphere. Provision can be made for surrounding the tubes with a flue gas atmosphere, so that the effects of external scaling can be taken into account as well.

Thermal Fatigue Testing—Reference has already been made to the difficulty of joining austenitic and ferritic materials due to the fatigue failure likely to result from the alternate heating and cooling of materials having different coefficients of expansion. More than 150 types of welded and mechanical joints have been investigated by thermal fatigue tests in which joints between ferritic and austenitic materials are subjected to rapid cycles of heating and cooling.

Engineering Research Section

Stress Analysis—The stress systems existing in such parts as drumheads, welded nozzle connections, etc., are extremely complex, but it is only by a thorough understanding of the stress distribution that pressure parts can be designed, and not made on a trial and error basis. Babcock & Wilcox were among the first in this country to apply electrical resistance strain gauges in the investigation of stresses in pressure parts, and a special technique has been developed which permits their application to the inside surfaces of vessels for water test at pressures up to 2,000 lb./sq. in.

Hydraulic Fatigue—The fact that many pressure parts operate under fatigue conditions has resulted in the application of fatigue testing to destruction to full-size experimental vessels. The equipment used is capable of subjecting them to a hydraulic pressure of up to 2,000 lb./sq. in. six times a minute. High speed Werner & Pfleiderer equipment is now being installed at the Research Station which will be capable of subjecting test vessels to pressures up to 4,500 lb./sq. in. 80 times a minute.

Tubing—A considerable saving of material has resulted from the discovery that the maximum stress, on close-radius bends such as are used in superheater elements, is on the inside of the bends, where it is offset by the thickening of the metal there. Previously it had been assumed the maximum stress was on the outside of the bend with its thinner metal, and the thinning had been allowed for by using heavier gauge tubes throughout the superheater. A close study has also been made of the technique of making expanded joints and this has resulted in improvement in the tools and methods used, and the reliability of the resulting joints.

Ultrasonic Testing—A sub-section of the Engineering Research Section specialises in the application of physical methods to engineering problems, and an important part of its work has been the investigation of means, other than radiography, for the detection of faults in welds—in particular the use of ultrasonics. One of the more interesting methods used for the minute defects which might occur in connection with welds utilises, in effect, a multi-crystal transmitter and a single crystal receiver located on the other side of the test specimen. By rapid scanning of the multiple transmitters, after the manner of an elementary television raster, a pattern of spots is produced on the oscilloscope screen which shows up any flaws. This equipment is still in the experimental stage and suffers

Arrangement of strain gauges for stress analysis on boiler drums.

from the disadvantage that access to both sides of the specimens is required.

For such items as pipe-butt joints, which are accessible only from the outside, developments are taking place in the application of a shear wave technique, a sharply-refracted wave being emitted at a shallow angle into the pipe and being reflected from the joint.

Gas Temperature Measurement—Problems arising from the operation of large boiler plant render a knowledge of the true gas temperatures in various parts of the boiler of great importance. The gases are not under black body conditions and are freely radiating to comparatively cool surfaces, so that normal equipment cannot measure true gas temperature. High velocity suction pyrometers have been developed in the department, but although these give reliable gas temperature measurement, traverses of the gas passages cannot be made because of the large size of present-day boilers.

Work has been carried out on the sodium line reversal method in which a light from an incandescent lamp is projected through the gas, and the resultant light is examined spectroscopically. When the colour temperature of the lamp is below that of the gas, the spectrum shows the characteristic bright yellow sodium line emitted by the traces of sodium in the gas ; this changes to a black line when the lamp temperature rises above that of the gas. It is a comparatively simple matter to ascertain the temperature of the lamp filament at the point of reversal. This method has the disadvantage that it cannot be used for temperatures below about 1,100° C., and there are other difficulties in its use. An investigation is being conducted to examine the possibility of using the velocity of sound in gases as a means of measuring temperatures, and although the experimental difficulties are great, encouraging results have been obtained.

Fuel Testing Section

To those who may be under the impression that boilers are, if not mass produced, at least fairly standardised, it will come as a surprise to learn that a thorough examination of the fuel to be used is necessary before the design can be finalised. One naturally appreciates the need for such a procedure where brown coal or unusual vegetable matter may be used as fuel, but variations in ordinary coal from different sources can have an important bearing on design.

In the coal sampling room, fuels are first dried in an oven and then ground in small mills, the size of the sample being reduced as required, between successive grindings, by the use of rotary samplers. Calorific value is determined by bomb-type calorimeters of fairly conventional design, with one or two additional refinements. By the use of a telescope for thermometer readings, it is possible to read the temperature from outside the draught-proof cabinet to within approximately 0·001° F. To guard against slight sticking of the mercury causing errors in reading, a motor-driven "flapper" blade can be made to deliver a series of gentle taps without the operator opening the cabinet.

Ash and slag investigations are also carried out in this section, and include ash fusion temperature determinations and slag viscosity requirements, interest in which has been stimulated by slag-tap furnaces. Because of the necessity of keeping large boilers in operation, a special study has been made of the properties of the slag deposits which form on the outside of

Examining a butt-welded joint with ultrasonic testing equipment.

boiler tubes. To assist in this work, a Newton-Victor X-ray diffraction apparatus has recently been installed for the crystallographic examination and identification of these deposits.

Combustion Research Section

The activities of this section are mainly concerned with the development of new combustion processes, and the determination of the most suitable process for a given fuel. Among the various aspects of this work, reference may be made to pilot scale work on the "burnability" of a fuel, slurry utilisation, spreader stokers, pressurised combustion, pulverised fuel firing, and oil burner efficiency.

Research work is also carried out on problems arising from combustion, one of the principal ones being the fouling and corrosion of heat absorbing surfaces. A number of test rigs have been constructed, incorporating sections of heat-absorbing surfaces operating under full-scale conditions, and in this way the various factors in the problem are isolated and studied.

Telcon Metals Division

ARRANGEMENTS are being made to move the Metals Division of the Telegraph Construction and Maintenance Co., Ltd., from Telcon Works, Greenwich, to the satellite town of Crawley in Sussex where it is proposed to build a new factory for the production of the Company's special alloys which are widely used in the electrical, radio and communications industries. This move has been necessitated by the urgent need for expansion to meet the increasing demand for Telcon Metals, and will have the effect of doubling the present productive capacity. The first stage of the removal is not likely to take place for about 18 months.

Powder Metallurgy as a Research Tool

By H. W. Greenwood*

The powder metallurgy technique has now been established as the best method—in some cases the only method—of making a number of components and materials in general use. In this article, the author draws attention to the advantages of using powder metallurgical methods in research work.

EARLY this year, the Birmingham Local Section of the Institute of Metals held a discussion on " New Techniques of Metallurgical Research." The inclusion of a paper[1] on the contribution which the methods and processes of powder metallurgy could contribute was implicit recognition of its value as a research tool. The authors of that paper said that the " electrical and telephone industries have accepted the powder metallurgical approach to the investigation of metals having high melting points," and went on to say that the same approach could be applied successfully in other fields. This is an experience common to all who have any wide knowledge of powder metallurgy, but, as yet, it cannot be claimed that a large number of technicians have such knowledge. It may be of service, therefore, to suggest that the powder metallurgical technique offers many real advantages both in the direction of economy in materials and apparatus, and in permitting close control over conditions. In this way, the study of such problems as, for example, the effect of very small variations in composition, and the effect of additions of both metallic and non-metallic substances on the physical properties and structure of metals, is facilitated.

It is of particular interest to note that each phase of development of powder metallurgy has provided important contributions to research methods, in addition to aiding the production of particular materials ; also, these methods have expanded beyond anything that could have been expected at their inception. As an example, we have Wollaston's method of producing ductile platinum, which we look upon as initiating powder methods, and which has provided means of producing ductile refractory metals that are in use to-day. It is significant that all the advances in arc-furnaces, and in thermo-chemical and induction heating methods, have failed to give us ductile refractory metals, and that the powder metallurgical method is unique in this particular field. The second important product of powder metallurgy, the porous oil-impregnated bearing, has equally developed along many lines, so that to-day we produce and apply a numerous progeny of porous filters, sweat-cooled turbine blades, proximity fuses, and the wide range of impregnated or infiltrated alloys whose excellent properties and wide application are only just being recognised. Yet another field of enormous importance to industry is that of the hard metals, wholly powder metallurgical products, the future prospects of which can only be said to be infinite. Granted all this, it may still be of service to provide some more detailed examples of the actual use of the powder metallurgical technique as a research tool which may suggest a wider selection of possible applications.

Effect of Minor Constituents

An outstanding feature of metallurgy and its development in recent years has been the recognition of the importance of the part played by constituents present, not in " large " proportions, but often to the extent of only a few parts per thousand. Another factor of great importance has been the demand for alloys and metals having outstanding physical properties at temperatures many hundreds of degrees above anything that was envisaged only a few years ago. In many respects it may be said that, whereas metals in the past were called upon to have static properties, to-day it is, in the main, dynamic conditions which have to be satisfied. The difference is, perhaps, clearly contrasted when we compare the reciprocating steam engine with the gas turbine. Notwithstanding the progress already made, it is clear that we are only on the threshold of a new era in which high temperature resistant alloys will play a predominant part. To attain the desired properties, and to maintain them, we shall obviously have to step outside the circle of pure metals and make use, possibly extensive use, of non-metallic materials such as refractory oxides, borides and boron, and other agents capable of exerting considerable influence on the properties of the metals and alloys to which they are added. This is all the more likely in that many of the rarer metals that we have used in the preparation of alloy steels and the like are showing signs of scarcity, and will certainly have to be replaced sooner or later ; in addition to this, we have, in many cases, apparently reached the limit of conditions they can satisfy. It is in testing the effect of such additions that the powder metallurgical methods can be of such outstanding service. It is quite well known that there are tremendous differences between the effect of particular elements on steel, and that by a right choice one can obtain the same order of effect, for example, on the hardening of steel by the addition of 0·0012% of boron as by adding 1·33% nickel, 0·31% chromium, and 0·04% molybdenum.[2] This represents a saving of 1·68 tons of alloying elements on every 100 tons of steel, or nearly 200 times the weight of boron used to attain the same result. Investigations of this type of substitution are very easily and simply carried out by powder metallurgy.

One of the major interests of the metallurgist to-day is grain-size in metals and alloys and its control. It is common knowledge that one may have conditions in which grain growth is rapid with increasing temperature,

* Powder Metallurgy, Ltd., London.

1 Pitkin, W. R., and Jones, D. J., *Metal Treatment*, 1952, **XIX**, April, 168–169.

2 *Metal Progress*, July, 1951, p. 52.

and that quite small additions of particular elements or compounds can profoundly affect this grain growth so that, if desired, one can have a considerable increase of grain size, reaching a maximum at some particular temperature and thereafter not changing much. On the other hand, one can make a small addition of a substance and the increased temperatures will have little or no effect on grain size. The convenience of using powder metallurgy for work of this kind can hardly be exaggerated; additions can be made to alloy powder with great accuracy, and mixing by ball milling offers no difficulty. Pressing can be at any suitable figure, and the sintering operation can be under the closest control both as to temperature, time and atmosphere. Duplicate experiments offer no difficulties for the whole series of operations are carried out in the same manner, and approximately simultaneously, whether one test piece or a dozen are required.

Precipitation Hardening Investigations

A fertile field to-day is that of the alloys which are capable of age- or precipitation-hardening, and of special interest is the case of those porous parts produced by powder metallurgy and then infiltrated or impregnated with a second metal or alloy. Some valuable combinations have been those in which a porous iron skeleton has been infiltrated with a copper-aluminium alloy capable of precipitation-hardening. In one well-known example, some millions of compressor blades for jet aero engines have been produced by this technique which, after heat treatment, have an ultimate strength of 100,000 lb./sq. in. (44·6 tons/sq. in.). Another property possessed by these particular blades is excellent damping capacity, a quality which appreciably extends their vibration fatigue life. In this particular case the porous iron parts or skeletons are infiltrated with a liquid copper-aluminium alloy with 4% aluminium at about 1,040° C. (1,900° F.).

Results of investigations undertaken in this country as well as in the United States have shown how susceptible many of the age-hardening alloys are to the presence of quite minute quantities of various elements, and have suggested the very wide measure of control which such additions confer. It has been shown that additions of from five parts per ten thousand to one part per thousand of elements such as antimony, cadmium, indium and tin can appreciably influence ageing[3] of a normal aluminium-copper-titanium alloy, and that the further addition of small amounts, (six parts per ten thousand) of magnesium can also play a part, but not always in the same direction. The mention of magnesium will remind those who have had much experience with this metal of its power, in very small quantities, of affecting the properties of alloys and metals to which it is added. In almost all these cases, and many could be cited, the effects caused are of a magnitude that bear no relation to the quantities involved, as for example in the production of nodular or ductile cast iron, when it is added to the molten metal in the ladle to the extent of one or two parts per thousand: cerium acts in much the same manner as magnesium. Another substance acting in quite a different manner is alumina, which in a range of alloys appears to have a remarkable influence on grain size, or on grain growth. Quantities of the order of two parts per thousand have been used in successfully maintaining fine-grained structures and inhibiting grain growth in nickel-aluminium alloys annealed at 1,000° C. for 30 minutes in hydrogen,[1] whereas in the absence of alumina a definitely coarse-grained structure developed under the same conditions.

So far, the applicability of powder metallurgy to the study of metals and combinations of metals which in normal conditions are immiscible has not been mentioned, because it is taken for granted that, to-day, the fact that powder metallurgy can handle a very wide range of such immiscible materials is as well known as that the normal limitations of the phase rule are equally invalid in powder metallurgy.

Non-Metallic Additions

From the research point of view, one cannot overstress the importance and value of the powder metallurgical technique in dealing not only with metals that normally are immiscible, but also with mixtures of metals and non-metallic materials such as carbides, oxides, nitrides and other compounds having properties that give them great importance to-day. Not only is it possible to investigate the effect of such substances upon metals, but a number of them offer possibilities when subjected to pressing and sintering that are of the greatest interest, as witness the production of cutting tools from pure alumina. It is also widely recognised that the addition of such materials, and especially of oxides, can exercise a remarkably beneficial effect on the physical properties of a wide range of metals. It is becoming clear that only small improvements are to be expected from alloys based on iron, nickel, and cobalt, as far as gas-turbine materials for use at increasingly higher temperatures are concerned, and that much more attention must be paid to combinations of metals with oxides and similar refractory substances including ceramic materials and/or ceramic-metal mixtures. A notable example of this is indicated in a recent German patent application,[4] in which claims are made for surprisingly good results obtained when small quantities of tungstic and chromic oxides are added to iron-copper powder mixtures. An untreated iron-copper mixture containing 92·5% iron and 7·5% copper showed a dimensional increase on sintering of 1·93%, and a tensile strength of 16·3 tons/sq. in. The addition of 0·5% tungstic oxide reduced the dimensional change to 0·44% and increased the tensile strength to 22·5 tons/sq. in. When 0·5% chromic oxide was present, 0·5% tungstic oxide reduced the dimensional change to 0·25% and gave a tensile strength of 21·5 tons/sq. in. Effects of this order have a practical value that needs no emphasis. The technique is that of powder metallurgy and results of an equally interesting and valuable character have been obtained by the addition of small amounts of alumina and magnesia to other alloys. At present, such work is only at the exploratory stage, but a glance at the results so far obtained shows the great potentialities. In many cases, the amount of the additions necessary are so small as to be of the same order as many impurities in commercial metals. It is safe to say that experience has shown that many effects induced by extremely small amounts of impurity bear no relation to the actual quantity of that impurity that has to be present. Now we use the knowledge of the effect of impurities to control the properties of metals or alloys in the direction we require.

3 Hardy, H. K., *J. Inst. Metals*, 1950, **78**, 169.

4 German Pat. Appl. 18b, 23, H9762, Sept. 17, 1951.

Other Applications

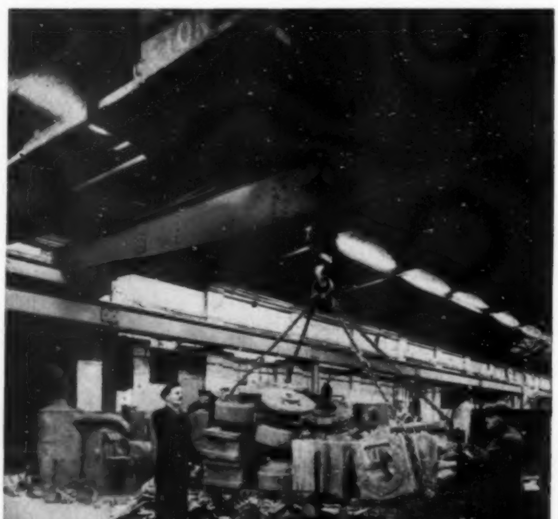
Probably the most fruitful field in this direction at the moment is that of the alloys capable of age- or precipitation-hardening, where it is possible to accelerate or to reduce the rate of hardening and so control reactions that normally take appreciable time to reach completion. In powder metallurgy, there is already an accumulation of valuable knowledge and experience on the influence of small additions of elements on such characters as the form of the powder particle. An example may be found in the addition of a small proportion of silicon to stainless steel as an aid to the obtaining of a non-spherical powder with enhanced sinterability. Another example is the effect of iron content on the shape of nickel particles. Here the effect is the opposite of that of silicon on stainless steel. Nickel powder particles, especially nickel produced from the carbonyl, are polygonal in form, but if iron is present in quantities exceeding 1%, the particles are spherical and possess the onion skin structure associated with carbonyl iron. An even better known example of the effect of a small addition of an impurity is the introduction of a few hundredths of a per cent. of sulphur into nickel-iron-molybdenum alloys of the Permalloy type. Such metal when cast can be hot-rolled to produce a fine grain structure which at room temperature is so brittle that it is easily ground into powder. Another interesting case is that of 18 : 8 stainless steel containing from one to two tenths of a per. cent. of carbon. When this is heated at a temperature of 500–750° C. the carbon, in the form of chromium carbides, is precipitated at and on grain boundaries. This is now called a sensitised alloy and, if boiled in a solution of copper sulphate and sulphuric acid, the grain boundaries are attacked and the alloy embrittled to such an extent as to be easily powderable. That is the basis of the Wulff method of making stainless steel powder. The recital of these various methods of using impurities to influence either grain form of powders, or the physical properties of sintered compacts made from them, and the increased control, as well as understanding of the mechanism of such reactions as those involved in age- or precipitation-hardening, provides justification for the claim that metallurgical research using powder metallurgical methods can offer possibilities and results attainable by no other methods. The ease with which refractory metals, or such metals and their oxides or other compounds can be introduced, and the accuracy with which perfect distribution of very small percentage can be obtained is quite unique. It is true that in many cases it is only too clear that a vast amount of further investigation is necessary, but the one great advantage is that the method has been thoroughly tried out and found effective. It is also true that the method is open to test by anyone, and it is not difficult to attain to a reasonable competency in the use of powder metallurgical methods. All this is a strong recommendation for the greater use of the powder metallurgical technique in metallurgical research. To-day it can be a matter of choice, to-morrow it will be a matter of compulsion.

Cold Cathode Lighting in a Foundry

LOCOMOTIVE wheel centres, traction motor castings and track links for tanks, excavators and cranes are products in which the steel foundry division of K. and L. Steelfounders and Engineers Ltd., Letchworth, specialise. The cold cathode lighting in the foundry where they are made was installed after the company had studied various methods of lighting in different parts of the factory. Cold cathode lighting, originally adopted as an experimental replacement for tungsten illumination, is now being extended to the remainder of the foundry, and has also been installed in a steel store.

The General Electric Co. Ltd., supplied for this installation three-light 9 ft. F.9005 cold cathode fittings, with two modifications designed to meet the abnormally dust-laden and corrosive atmosphere of foundry work. First, the reflectors are vitreous enamelled instead of stove enamelled. Secondly, the tops are closed instead of slotted.

The fittings were mounted above the crane rails at a height of 16 ft. and 24 ft. from ground level. It will be seen from the illustration that the use of an almost continuous light source has reduced shadows under the crane to an absolute minimum, eliminating the necessity for additional lighting under the crane. 66 fittings are arranged in two rows with a 25 ft. spacing between rows. The installation is planned for an average illumination through life of 8 lumens per sq. ft. at floor level.



View showing adequecy of lighting beneath crane.

In the steel store, 18 standard open-top G.E.C. F.9005 cold cathode fittings supplied by The British Central Electric Co. Ltd., have been installed in three rows of six at a mounting height of 28 ft. giving an average illumination through life of 10 lumens per sq. ft. at floor level.

Iron and Steel Productivity

Report of British Team's U.S. Visit Published

The Report of the Iron and Steel Industry Productivity Team which visited the U.S.A. last year was published at the end of last month. In view of the important part played by iron and steel in the industrial and economic life of the country, this report may be described as one of outstanding interest. Its 143 *pages provide a full comparative account of the British and American heavy steel industries. A brief outline of the findings is presented here.*

THE latest Productivity Report, that of the Iron and Steel Industry Team, which visited the U.S.A. last year, was published at the end of June. The Team, led by Sir Charles Goodeve, consisted of five managers, five technicians and five workers, together with a Secretary, and it was charged with studying the organisation and methods of the United States' iron and steel industry, particularly those factors relevant to the comparative productivity of the U.S. and U.K. industries, with a view to recommending how far and by what methods the principles and experience of the U.S. industry could, with benefit, be applied or adapted in the U.K.

Before its visit to the U.S.A., the Team paid a number of preparatory visits to works in this country to enable its organisation into study groups to be worked out. In all, eight American works were visited, five being in the south and west of the United States. These were chosen partly because many members of British steel companies, including two members of the Team, had seen works in the traditional steelmaking areas of Pittsburgh and Chicago within the past two years.

The material standard of living in America is probably twice as high as in any European country, and this is reflected in a correspondingly high consumption of steel. Although this high standard of living is partly the outcome of historical forces and of the character of the American people, its indispensable foundation is provided by the country's exceptional natural resources. The enormous reserves of ore in the Lake Superior region and of coking coal in the Allegheny mountains, linked by the Great Lakes natural waterway system, resulted in a concentration of iron and steel production in the Great Lakes district. This situation is very different from that obtaining in Britain, where most of the coalfields are much less than 100 miles from seaports, and fully half the iron ore consumed (in terms of iron content) is imported.

The geographical concentration of steel output in America is matched by its concentration in large works. This has been encouraged by the great distances separating the raw materials, the mechanisation resulting from the labour shortage, the amalgamation of firms due to intensive competition, the large market, and the fact that a high proportion of the American industry is of recent construction, due mainly to the rapid expansion of population and to Government investment and taxation concessions for defence purposes. These factors are primarily responsible for the high productivity in the American steel industry, which is broadly twice that in the U.K. industry. Other contributing factors are the standardisation of sizes and qualities, the high proportion of sales through stockholding merchants, who place bulk orders on the mills, and the larger total earnings available for capital expenditure. Some of these factors, however, involve higher costs in other directions.

Productivity in Steelmaking

In each of the three main processes—ironmaking, steelmaking and rolling—there are four principal items of cost: raw materials, fuels, wages and depreciation and other overheads. The value of the final product is the sum of all these components, the relative values of which vary considerably from works to works and from country to country. A comparison of the costs in the U.S. and U.K. shows some interesting features. For example, in both countries 80% of the cost of making iron is in the materials and coke; fuel costs in the steelmaking and rolling stages in the U.S. are lower than those in the U.K.—due mainly to the lower price of fuel oil and gas in America; the higher U.S. wage rates are offset by the lower consumption of man hours per ton of product; and the total labour component in both countries generally represents about 25% of the total cost of making a heavy steel product. Transport, including the transport component in the cost of material and fuel is about 16% in the U.S. and 10% in the U.K. It must be remembered, however, that these components of cost are closely interlocked. Thus, cheaper ores can be used at the cost of extra coke consumption, and fuel can be saved by increasing capital expenditure.

The study of the efficient utilisation of the four resources—materials, fuel, labour and plant—which correspond approximately to the four items of cost, is the sphere of productivity. From a statistical point of view, plant productivity is the better starting point for comparisons than labour productivity, but in both cases U.S. figures are substantially higher than those for the U.K., the difference being greatest in ironmaking and least in hot rolling.

Ironmaking

The high productivity of American blast furnaces (2·8 : 1) is, in part, due to the higher and more regular iron content of the ores used, and the fact that only 10% of American output goes to foundries, compared with over 20% in the U.K. Since the British foundry iron furnaces are older and smaller, this lowers the average productivity considerably. The main reasons for the high productivity are, however, the larger size of the furnaces and the faster driving rates. At present the average effective size is 87% larger in America, but modern furnaces of the types now being built in Britain have a capacity, so far as size is concerned, two or three times greater than the present national average. It is

recommended that for furnaces on basic iron, a minimum hearth diameter of 25 ft. for imported ore and 27 ft. for home ore should be accepted as a normal standard in new developments. American furnaces are driven 35% harder than British and the Team considers that the factors limiting the driving rate of British furnaces should be investigated more closely. These include the greater cost and scarcity of coke, the better quality of American coke, and the age and size of British furnaces.

More direct control of the British industries' seaborne ores is being developed, and this should result in improved furnace operation by minimising the excessive number of burden changes now necessary. Britain in no way lags behind America in ore treatment, but much remains to be done in this field and in the improvement of uniformity and quality of coke supplies.

Steelmaking

The section on steelmaking deals generally with basic open-hearth steel, which accounted for 88·7% of the total U.S. output and 81·8% of the total U.K. output of steel in 1950. Steelmaking has developed along different lines in the two countries, because more scrap is used in Britain and British iron contains more phosphorus and sulphur. The U.S.A. also has the great advantage of cheap fuel oil and natural gas, with which over 90% of its open-hearth steel is made. The cold metal process in both countries has a much lower productivity than the hot metal process, a factor which has an appreciable effect on the total productivity, as the cold process accounts for 42·8% of British capacity and only 9·2% of American. Furthermore, this British capacity consists of a large number of small furnaces driven at a low rate.

The fixed furnace hot metal process accounts for 34·5% of British capacity as against 77·4% in America. American furnaces are some 45% larger and driven 8% harder, with a 30% smaller shift manning. Improved productivity in this process could be obtained by using larger furnaces, more handling equipment and fewer men. The tilting process, which is of growing importance in the U.K. owing to the need to use high phosphorus iron, has a creditable productivity performance. Its driving rate could, however, be increased, possibly by the introduction of some intermediate refining.

The acid-duplex process yields very high productivities in America, but only, of course, with the help of additional plant in the shape of Bessemer converters. Where conditions are favourable, this process should be re-introduced in the U.K.

The driving rate in taps per week is maintained as the size of furnace increases, but as the rolling of ingots is a continuous process a minimum of six furnaces tapping at regular and successive intervals, is required to keep a cogging mill operating steadily. The size of furnace is, therefore, ultimately governed by the size of the works.

Taking all factors into consideration, it is recommended that new furnaces should not be smaller than 150 tons in the cold metal process, 200–250 tons for the fixed furnace hot metal process (low or moderate phosphorus) and 300–400 tons with the tilting furnace hot metal process (with high phosphorus).

Furnace design and methods of control are probably more advanced in Britain than in America, but American melting shops are in general better laid out for ease of maintenance. By consciously designing the layout of the melting shop to permit freer access for mechanical handling equipment, making possible rapid repairs, the Americans have achieved a furnace availability figure of 91% as compared with 80% for Britain, with a smaller maintenance man-power requirement, and in spite of the fact that the furnaces are driven harder. Some improvement in Britain could probably be obtained with modest capital expenditure.

Rolling Mills

Although productivity comparisons in this field are difficult, it seems that, in general, the capacity of the average American mill in heavy steel products is 50% to 100% greater than the British, working up to 160 hours per week compared with 127½ hours in this country. The size of ingot rolled may be somewhat larger in America, but the main causes of higher productivity lie in the nature of the equipment, the rolling mill practice, and the type of end product. Frequently American mills have a greater number of independent drives and, therefore, a high total horsepower, and the layouts are specially suitable for rolling large tonnages of fairly standardised products. The speed of rolling has been increased by the introduction of a number of mechanical aids to reduce the manual effort required.

The importance of the primary mill is emphasised, and it is pointed out that such mills of high capacity can give a high productivity and a low overall operating cost. New primary mills in Britain should have a potential capacity of not less than 750,000 tons, and preferably 1,000,000 tons, per annum. Under the present development plans, the number of mills with such a potential capacity is being increased. For the most efficient operation, the secondary mills should be such that the primary mill is loaded to full capacity, additional finishing stands being installed where necessary.

It is suggested that serious consideration should be given to the American 3-high layout for any future British development in medium size sections. By the provision of extra stands and drives, it is possible on this type of mill to roll more bars simultaneously and at higher speed, and the manning is reduced to a minimum since it is possible to provide automatic manipulation devices. A high-capacity universal beam mill of the American type has been proposed for installation in Britain, and this will enable the full range of sizes and weights to be produced. Future plate mill installations in Britain are being designed with a 2-high breakdown stand, or broadsiding unit, and a 4-high working stand, in accordance with modern American layout.

The smaller number of sizes rolled in America, and the elimination of small tonnage orders and odd sizes, is of great advantage to productivity.

Fuel and Refractories

The U.S.A. has the enormous advantage of having abundant supplies of cheap, high-grade coking coal, oil and natural gas. The degree of fuel integration in American works is less in those districts where rich fuels such as natural gas and oil are available, and blast furnace gas is, therefore, not used to any extent.

The use of fuels having a high calorific value, and developing high flame temperatures, accounts for a reduction of at least 10% in American open-hearth fuel rates compared with British. The American rate is further reduced by the lower metallurgical load, furnaces designed for known fuels and raw materials, and adequate

charging facilities. In addition, the use of large furnaces reduces the fuel consumption per ton of ingot.

Due to the high percentage of hot ingots charged, first-class instrumentation, universally applied control gear and heating programmes scheduled in detail with reference to track times and steel quality, the fuel consumption in soaking pits is considerably lower in America.

Slightly better silica bricks and considerably better fire bricks are available in America, but basic bricks are of a similar standard in both countries. The use of basic ends on open-hearth furnaces, extensive furnace cooling and the use of archless water-cooled door frames give American practice some advantage over British. Extensive use is made of magnesite ramming mixers for hearth construction, and doors are rammed with plastic basic material. In terms of "unit roof life," British practice is better than American, but linings, basic ends and checkers have longer lives in American furnaces. Both new and repaired furnaces are brought up to steel-making temperature from cold much more quickly than in Britain. Apart from the advantage inherent in larger furnaces, the refractories consumption per ton of ingots is greater in Britain on account of the high metallurgical load.

Management and Labour

Manning is reduced to a minimum in the U.S.A., machines and mechanical aids being used to minimise labour and to speed the rate of working. Relief men are employed to enable mills to roll greater tonnages per shift, and rota working schedules, on a 40-hour man-week basis, facilitate the working of rolling mills for up to 20 shifts per week. Because standing times are staggered over the week, it is possible to make the most economical and efficient use of maintenance workers. All sections of the plant work 52 weeks per year, holidays being taken in relays.

Although the relations between management and labour seem less stable than in Britain, the system of representation of all employees at one works by a single union avoids the complex problems which arise in this country. Biennial wage contracts between management and unions are strictly systematised, using as a basis a method of job evaluation in which every job is assigned to one of 32 wage classification groups, dependent on the training, skill, responsibility, effort, surroundings and hazards involved. This is claimed to have eliminated inequalities previously existing and to have reduced grievances.

Rather surprisingly, output bonus schemes are somewhat less common in America than in this country, but where they exist they are direct and effective. When account is taken of the difference in prices, and the effect of taxation and subsidies, it is thought that the lowest paid American steel workers can probably—and the average worker certainly—buy more goods than his British counterpart.

In the works visited, American training methods and opportunities for promotion are no better than those in the more progressive steel firms in Britain, but owing to the concentration into a few large organisations, the general training standard may be higher. Safety consciousness and safety records appear to be substantially better, and it is recommended that intensive efforts should be made to improve the British position in this respect.

Works' Size and Transport

The Team recommend that all integrated steel works should aim at an annual capacity of 750,000 up to 1,000,000 ingot tons, which would permit reasonably high-capacity units of plant to be incorporated; such works would at the same time have a high degree of flexibility. In the case of cold metal plants, the recommended minimum figures are 300,000 tons per annum for merchant and special products and 500,000 tons for heavy steel products.

It is also suggested that steel works should take in more finishing processes and so provide a better balance of employment for local labour, permit a closer technical link between the various stages of the process, and allow closer integration of fuel and supplies of raw materials, such as scrap.

The development of heavy steel production in works attaining these standards of size presents a number of problems, both technical and sociological.

Considerable improvement is possible in transport both inside and outside the steelworks, and the use of radio communication for internal transport is recommended as an aid to increased efficiency. Outside the works, the apparent low productivity both of labour and of rolling stock will have to be examined, especially with the object of increasing wagon and train loads above their present low values, if the rail transport charges are to be reduced from their present figure of 10% of the cost of the steel. The importance of road transport in handling all general works materials and products should not be underestimated, and in a number of cases better access to certain parts of the works should be provided.

Plant Maintenance

The success of the maintenance department may be measured by the amount of down-time due to unplanned stoppages and the number of man-hours consumed. In both respects the American figures are good, and considerably better than British with regard to man-hours. The reasons for this are mainly as follows:—(*a*) the layout, operation and capacity of the mills is such that planned stop days are arranged during the week and are not concentrated into the week-end as in Britain; this permits a better work load on the maintenance department; (*b*) lubrication is organised in a special department and mechanised wherever possible; and (*c*) plant design is very robust and well above the operating capacity required.

Costing and Statistical Records

Whilst existing techniques were not found to be any better or on a more uniform basis in America than in Britain, there are considerable variations in both countries in the degree of cost-consciousness and the extent to which cost data are used. Performance statistics and, so far as possible, costs, should be made available to all levels of management, and interest in them should be stimulated by frequent and regular discussions based on cost reports and statements.

Manning records should be kept on a standard basis so that comparisons can be made between various periods and conditions. Such records should be combined with plant output rates (such as furnace productivities) to produce regular information on labour productivities or on labour consumption rates.

The collection of statistics should be a means to an end and not an end in itself, and a few man-hours spent in summarising information and suggesting conclusions may save management many hours in assimilating such information. The Team suggest that the exchange of plant performance statistics between works in which conditions of operation are reasonably comparable would be a stimulus to the competitive spirit in the British steel industry.

Marketing

American steel marketing policy reflects the scale, the dynamic expansion and the higher degree of standardisation in the steel-consuming industries. These have fostered optimism and risk-taking in the development of markets for the products of new types of large mills and for other new products. Post-war developments in the British steel industry have made, or will make, most of these new products available in this country, and there should be similar possibilities of developing the market. An aggressive marketing policy will, however, be necessary.

Productivity in the U.S. industry is also assisted by the active discouragement of small orders and of special qualities and sizes. This is achieved by charging high extras for small orders and by refusing orders for less than certain minimum quantities. From the consumer's point of view, the higher productivity achieved in the large and specialised American works is partly offset by the high charges made by stockholding merchants for their services in handling a large proportion of the output.

The benefits of producing large quantities in a concentrated area can be more than offset by the costs of distribution to more remote markets, and this factor accounts for the present American trend towards decentralisation. This is further encouraged by the more favourable freight rates on raw materials than on finished steel.

Research and Technical Progress

The high standard of engineering design in American steelworks is due mainly to the strong and active plant engineering industry, coupled with the progressive outlook of American steelworks engineers. Ample spare resources exist to build and operate pilot plants even for processes which are somewhat speculative.

Research in the American steel industry is on a relatively small scale, owing perhaps to its comparatively simple metallurgical problems. Ferrous metallurgical research in the country as a whole is on an extensive scale, and receives considerable financial assistance from the Government and from the using industries.

Research in the British industry continues to be strong and even to increase in strength, but its practical application suffers from many obstacles at the present time. Co-operative research in Britain has been found to be an efficient way of increasing the technical strength of the industry. It has developed on a much larger scale than in the U.S.

Finance and Development

Gross profits in 1950 of the American steel industry were nearly twice the British rate and, despite a higher rate of taxation, higher dividends were paid and larger surpluses retained in the business. Despite lower profit rates, the British industry has over past years re-invested accumulated surpluses of the same relative magnitude as the American.

American firms are allowed by the Government to write off capital cost of plant and buildings more rapidly than are British firms. This reflects the American attitude that the life of a plant is limited by obsolescence arising from technical development and improvements made by competitors rather than by the rate at which it wears out.

Special tax allowances have, when operating, provided almost equal incentives to development in the American and British industries. The periods when these have operated have, however, been significantly shorter in Britain.

The capital cost of an integrated steelworks on a new site is estimated at £75 per ingot ton of capacity.

The current rate of capital re-equipment of the British steel industry of £60 million a year must be at least maintained.

Any major reduction in the cost of making steel is dependent on the co-operation of the coal industry, the railways and the capital equipment industry. A higher proportion of our limited national resources needs to be devoted to capital investment in these industries.

Gravity Aids Nickel Ore Recovery

Nature's old standby, the force of gravity, has been put to work deep beneath the earth's surface in a vast mining programme that is helping to maintain the free world's supply of nickel. It has given mining science the key to the recovery of millions of tons of nickel-copper ore once regarded as worthless. Engineers of The International Nickel Co. of Canada, Ltd., at its mines in the Sudbury District of Canada, have recently adapted a mining technique by which gigantic masses of ore, far underground, are induced to cave and disintegrate of their own weight, according to R. L. Beattie, Vice-President and General Manager of the company's Canadian operations. Inco's engineers took their cue from observation of the natural tendency of the lower grade ore to subside and break up after higher grade ore beneath it was mined out.

Called "induced caving," this low-cost bulk mining method, plus metallurgical practices, makes it practicable for Inco to recover and treat ore lower in grade than it had ever worked in underground mining. Thus the supply of economically available ore has been broadened, aiding Inco in maintaining its current nickel production at a post-war high. In caving, a "slice" which may contain as much as 1,500,000 tons of ore is undercut. As ore from the undercut slice is withdrawn, the slice to be mined breaks away and starts to disintegrate as it moves downward, the weight of the upper part of the mass acting so as to crush the ore at the bottom.

Another bulk mining technique by which Inco is boosting its underground production is the "blasthole" method. Blasthole mining differs from caving only insofar as explosives are used to break the slices of harder, tougher ore from the solid material. The force of gravity then takes over, as in caving.

In addition to these recent innovations, the company continues to use a number of other mining methods by which the higher grade ores are extracted with relatively little dilution as in the past.

G.W.B. Comes of Age

EARLY in 1931, before Britain had recovered from the trade depression, a company was formed, whose future success was based on confidence in British industry as a whole, and on the expansion of the industrial use of electricity in particular. G.W.B. Electric Furnaces, Limited, of Dibdale Works, Dudley, Worcs., was the logical outcome of an agreement between Gibbons Bros., Ltd., and Wild-Barfield Electric Furnaces, Ltd. The former had long been known as producers of large scale fuel-fired industrial furnaces, while the name of Wild-Barfield is widely acknowledged as one of the pioneers in the electric furnace industry, normally concerned with the design and manufacture of medium and small units.

The need for large, purpose-designed furnaces was becoming more and more apparent and it was with this in mind that G.W.B. commenced business in premises at North Road, Holloway, London, but by 1939 it became imperative that larger production space should be found. In consequence, the manufacturing facilities of this company transferred to Dibdale Works, Dudley. Even this expansion failed to meet the needs of the company and since then extensions have been provided and recently a new office block added.

The company's first order was for a box-type sheet annealing furnace from the Northern Aluminium Co., Ltd., and it is worthy of note that this set the seal on a long association with the aluminium industry which has grown to the point where G.W.B. are one of the leading suppliers of electric furnace equipment for the heat-treatment of light alloys.

Furnaces in course of manufacture.

It was the close investigation into the needs of the light alloy industry that led to the development of a means of high speed forced convection by centrifugal fans and directional air flow to impart heat to the charge. Heating up times were thereby reduced to approximately 50% of what had previously been achieved when utilising the common paddle type fan for low speed air turbulence.

Apart from the light alloy industry, G.W.B. have also supplied a large quantity of equipment for most other types of non-ferrous and ferrous heat-treatment including the automobile and aircraft industries requirements.

Present developments include G.W.B.'s entry into the arc furnace field and several large contracts are well under way. Further, there will shortly be put on the market, induction heating equipment working on medium frequencies utilising a mercury arc rectifier as a means of frequency changing. This latter equipment has been evolved in co-operation with the English Electric Co., Ltd. Finally, low frequency induction heating and melting equipment can now be supplied.

Apart from the manufacture of electric furnaces, G.W.B. are engaged in two other important activities, not unconnected with the main production. Firstly, there is a separate works in Birmingham solely manufacturing and distributing the widely used case-hardening compound known as "Eternite." In addition there are "Nokase" anti-carburising mixture prepared in the form of clay, paint or powder, "Kleenard" and open hearth hardening compound and finally "Speedicase" a rapid case hardening paste giving the speed of a liquid bath and used for fast medium depth work. The other activity concerns the rapid and successful development, since the last war, of electrode type steam raisers and water heaters.

The extremely wide application of the latter products had again necessitated expansion of production facilities. Applications of the steam raisers include dairy sterilisation, tanning, granodising and the provision of steam for the testing of locomotive valves. The water heaters are primarily designed for space heating in conjunction with thermal storage systems, as in the new plant at the North-Western Electricity Board's Didsbury Offices.

New Roll Foundry at Crewe

General view of the administration block.

ALTHOUGH the Midlands is an important centre for the hot and cold rolling of non-ferrous metals, and for the re-rolling of steel, the enormous tonnages of rolled products turned out by the steel industry are mainly produced elsewhere. The importance of the Black Country in the early days of the iron and steel industry, however, resulted in the few foundries specialising in roll manufacture being concentrated in the area. Most of these early foundries had restricted sites and were usually served by canal but without railway sidings.

The most progressive of these roll foundries have kept abreast of modern requirements and it was by the fusion of two of them, C. Akrill, Ltd., of West Bromwich and Thomas Perry, Ltd., of Bilston, with R. B. Tennant, Ltd., of Coatbridge, Scotland, that the British Rollmakers Corporation, Ltd., was formed in 1942. For a number of years the three companies acted in close liaison, and their joint association with an American company confirmed the belief that only an integrated group of companies could provide the basis for the expenditure necessary to put their respective plants into a condition capable of meeting the demands occasioned by developments taking place throughout the world.

In 1944, the Corporation acquired the roll businesses of Bayliss, Jones & Bayliss, Ltd., and John Lysaght, Ltd., both of Wolverhampton, and Bayliss Rolls, Ltd was formed to operate both these works until the new works at Crewe should be ready to take over their production. Early in 1952, Miller & Co., Ltd., Edinburgh, makers of rolls for materials other than metals, joined the Corporation.

As was stated earlier, the object in forming the Corporation was the development and modernisation of plants to meet expected demands, and a large scheme of expansion and modernisation of the Tennent works was prepared and put in hand in 1944. Much of the new plant is now in use and when the scheme is complete R. B. Tennent, Ltd., will have the largest and most modern works in the United Kingdom producing both cast steel and cast iron rolls.

Midland Rollmakers, Ltd., was formed in 1947 to control and co-ordinate the operation of the works of the Midland companies. Since 1930, the Akrill and Perry works have been extended to the capacity of their sites, and they are efficient units for the production of the full range of straight carbon and alloy cast iron rolls. The acquisition of the Bayliss and Lysaght foundries, also on limited sites, gave the Corporation the opportunity and conditions which justified its long-term plan to build new works on a new and unrestricted site to take care of developments not possible on the older sites.

The immediate and long-term objects were the transfer of the production of Bayliss Rolls, Ltd., from Wolverhampton to a more efficient works, the immediate expansion not possible elsewhere, the development in the Midlands of cast steel roll manufacture, and any further concentration of production which future conditions might require.

The New Works

A suitable 70 acre site was found at Weston Road, Crewe, within 10 minutes walk of Crewe Station. Work was started on site levelling, drainage, etc., in March, 1948, and in May, 1951, production commenced in a plant incorporating features resulting from more than 100 years' experience in roll production and collaboration with the most modern roll foundries in Europe and the U.S.A.

The essential feature of the layout of the works is the way in which allowance has been made for future expansion. The main works entrance and offices are situated on Weston Road, and the general plan provides for administration and commercial offices, technical and research buildings, canteen, medical and welfare centre, recreation grounds and social amenities on the north side of the entrance, and for the work's laboratory, foundry and machine shop on the south side.

Excellent transport facilities are provided, the main railway line connecting with adequate works sidings and with the various departments. In addition, concrete and tarmac roads allow access of road transport to all parts of the plant. A well-planned drainage system collects surface water from all buildings and roadways into a 39 in. main pipeline which outlets into Gresty Brook and is adequate for all future developments of the site. Electricity and water services are sufficient for considerable future expansion, and although coal and oil are the main fuels used at present, it is expected that extensions to the local gas board's plant will result in the satisfaction of any gas requirements contemplated.

Melting and Casting

The production departments are housed in two blocks, the foundry building and the machine shop. The former consists of four main bays, two of 80 ft. span and two of 60 ft. span, and two intermediate bays of 40 ft. span, the overall length being 360 ft. The end bay houses the raw materials' storage facilities and main melting equipment. Bunker storage is provided for 600 tons of raw coal which is transferred to 25-ton hoppers above the independent unit coal pulverisers firing the four Gibbons air furnaces—two of 25 tons and two of 15 tons capacity—used for the production of certain irons of special composition. The pulverisers are No. 12 Herbert Atritors, driven at 1,350 r.p.m. by 50 h.p. 1,475 r.p.m. English Electric slip ring motors, and producing each hour 3,000 lb. of coal, pulverised to 80% through a 200 B.S.S. screen. The waste gases from the air furnaces are discharged to atmosphere by way of 80 ft. stacks lined to 5 ft. diameter.

In addition, there are two Pneulec cupolas, with 5 ft. 3 in. shells lined at present to 36 in. diameter to give an output of 4½ tons per hour. When increased output is required, bricking to 45 in. diameter will give 7 tons per hour at a coke ratio of 10 : 1. The charging platform is 18 ft. 6 in. from floor level. The 30 in. Keith Blackman fans, each providing 3,000 cu. ft. of air per minute, are designed to permit the use of an increased size of propeller to give 4,500 cu. ft. per minute.

The only other melting unit is a Stein & Atkinson rotary oil-fired furnace of a 30 cwt. nominal capacity and capable of 3–4 heats per day.

The Pneulec sand handling plant, which can deal with 6 cwt. per batch, is located in the moulding bay and draws screened and cleaned used sand from the stripping area and new sand from the adjacent storage bunkers. The moulders work on a clear concrete floor area unobstructed by chills, moulding boxes and tackle not actually in use. There are six oil-fired mould drying stoves by Foundry Refractories, Ltd., each 28 ft. long by 13 ft. 10 in. wide by 10 ft. high. The moulds are located on steel bogies, capable of carrying 100 tons, drawn into the stoves by heavy steel chains and electric winches and, after drying, are drawn into the casting bay for assembly and casting. The bogie control and back and front doors are all interlocked so that the bogie cannot be moved with the doors closed. The

Casting a chill cast iron sheet mill roll.

The machine shop—No. 1 bay.

casting bay is located between the moulding bay and the furnace bay and, as rolls are cast vertically in moulds made up of a number of slices (chilled or otherwise), the bay has a range of casting pits of reinforced concrete construction varying in depth from 8 ft. to 20 ft.

After stripping and fettling in the casting bay, the rolls are transferred to the machine shop by means of an electric transfer bogie which serves all bays of the foundry building and machine shops. Driven by a 15 h.p. D.C. motor fed with electricity by underground copper wires and roller current collector gear, this bogie is capable of carrying 40 tons at 200 ft./min. A further Glazebrook transfer car will be in use eventually.

The pattern shop and adjacent pattern stores run alongside and conveniently near to the moulding floor which they serve. Up-to-date pattern working machinery is installed and provision is made for a second floor extension to the pattern stores when necessary. A separate storage bay is provided for the accommodation of moulding boxes, foundry tackle and other heavy equipment when not in use, so as to clear the working floor of obstructions and to ensure that expensive equipment is stored under proper conditions. Chills, for instance, are stored in a bay which has heating pipes built into the concrete floor so as to prevent condensation and rusting which, if excessive, would result in scrapped castings.

Machining the Rolls

The machine shop consists of two main bays of 60 ft. span and an intermediate bay of 40 ft. span, the overall length being 330 ft. It is designed to carry overhead electric cranes up to 60 tons capacity and is equipped with a large range of sizes of modern roll and engineering lathes, wabbler milling machines and roll grinding machines capable of finishing all sizes and qualities of rolls to the closest tolerances.

Other machine tools are available for the machining of foundry and machine shop tackle, whilst the intermediate bay accommodates staff offices and a large tool room and tool store equipped with small precision machines to provide the shop with tool service, gauges and templates.

An interesting feature in the machine shop is the use of transparent plastic roof lights in order to avoid the cracking which occurs with glass due to the movements caused by overhead travelling cranes. In wet weather such cracking is a source of annoyance in any workshop,

but where fine finishes are required, as in the case of sheet rolls, the risk of rusting cannot be tolerated.

Both foundry and machine shops are planned to give an uninterrupted flow of production and to reduce bottlenecks and cross tracking to a minimum. The present buildings will accommodate additional plant which will double the production capacity of that now installed, and new plant is on order which will be in commission by the end of 1952. Subsequent additions to these buildings will deal with increased output of similar or different types of roll with no interference with current production.

The Brightside heating equipment includes two Lamont-type boilers each capable of providing 6 million B.Th.U's per hour, in the form of high pressure hot water, for heating all the main building blocks. These boilers are fired by automatic stokers which will operate down to 25% of the total capacity.

In the new works, every effort has been made to provide economically efficient and clean working conditions, to make heavy foundry and engineering work an agreeable job, and to provide for every reasonable comfort and amenity for the workpeople and staff. As part of this plan, each work's building has its own ablution block with lavatories, drying room, outdoor and works' clothes locker room, and shower and foot baths.

New and Revised British Standards

Methods for the Analysis of Aluminium and Aluminium Alloys—Part 4: Zinc (Polarographic Method). (B.S. 1728 : 1952)

Price 2s. Post Free

This British Standard method for the polarographic determination of zinc in aluminium and its alloys is published as an alternative to the mercuric thiocyanate method already published (Part 3). As with polarographic methods in general, it is particularly useful for alloys having a low zinc content and, over a range of 0·02 to 3% zinc, gives results having close agreement with the mercuric thiocyanate method. The method specifies the reagents used, recommended methods of sampling and test procedure. An indication of the reproducibility expected is given and is derived from experiments carried out by a number of independent analysts.

One-mark Graduated Flasks (B.S. 1792 : 1952)

Price 2s. Post Free

This British Standard has been prepared to cover a range of one-mark graduated flasks suitable for ordinary laboratory requirements. It specifies ten sizes of flask from 5 ml. to 2,000 ml. capacity. It gives full dimensions but, in accordance with current practice in British Standards for volumetric glassware, lists only the essential ones as mandatory, the remainder being given for the guidance of manufacturers. It includes a standard method for the determination of capacity and lists two classes of tolerances for this. It specifies requirements for material, construction, stability and graduation, and includes alternative shapes of neck suitable for stoppers of ground glass or plastics.

Chart Ranges for Temperature Recording Instruments (B.S.1794 : 1952)

Price 2s. Post Free

This British Standard makes recommendations for the temperature ranges of charts used in recording instruments actuated by: gas expansion, mercury-in-steel, platinum/rhodium v platinum thermocouple, resistance thermometer, radiation pyrometer.

As the preferred ranges have been compiled from data supplied by many instrument manufacturers their calculation has been achieved by grouping and consolidating the ranges favoured by individual users. Where minor differences in starting point and range were encountered during compilation they were embodied, wherever possible, in one range containing their maximum and minimum temperatures. There are in use many preferred ranges which are peculiar to a particular industry or process, and these have been included in the ranges specified in this standard. In most cases these special ranges have developed from the need to provide openness of scale at important temperatures, and their use requires some special arrangement of the measuring system in order to provide the necessary sensitivity.

Although these chart ranges embrace the whole of the useful temperature scale it is appreciated that not every instrument manufacturer will be in a position to adopt them in their entirety, especially since some of them are for use in conjunction with particular types of measuring systems. Further, the use of the whole of such a comprehensive selection of ranges is unnecessary when instruments are manufactured for a particular section of industry.

British Standard for General Requirements for the Metal-Arc Welding of Mild Steel (B.S.1856 : 1952)

Price 5s. Post Free

This British Standard specifies the general requirements for the metal-arc welding of mild steel under normal conditions of manufacture and service. The standard includes parts dealing with materials, details of butt and fillet welds, information required by the welding organisation, welding equipment and electrodes, welding procedure, workmanship, welding operators' supervision and inspection, and heat treatment and testing. Appendix A gives useful information on butt welds including a full range of recommended preparations. Appendix B gives information on fillet welds.

The requirements are not all applicable to certain forms of construction nor does the standard specify allowable stresses in welds or methods for their testing. Reference should, therefore, be made to the standard for a specific application where such a standard exists. If no such standard is available for the type of construction required by the purchaser, B.S.1856 can itself be used provided that such additional requirements as are necessary in the specific case, e.g. permissible stresses in welds and the tests to be applied, are agreed between the purchaser and the contractor. The standard will be of value not only as a basis of contract but also as a useful reference for all concerned with metal-arc welding.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 24, Victoria Street, London, S.W.1.

The Institute of British Foundrymen
Annual Conference at Buxton

Judging by the interest shown in its Annual Conference, the Institute of British Foundrymen is growing from strength to strength. This year records were surely broken by the number of members and ladies who attended the recent meeting at Buxton. The technical sessions, covering a range of subjects of technical and practical interest, were set in a background of enjoyable social functions. The proceedings at the Conference are briefly reviewed.

THE Forty-Ninth Annual Conference of the Institute of British Foundrymen, held at Buxton, June 10th–14th inclusive, proved a great success and the Conference Committee and Stewards are to be congratulated on the excellent arrangements made for the convenience of members and guests. The Conference was remarkably well attended—indeed, it was probably a record in this respect—the weather was good, the business and technical sessions and the works visits were well attended and of real constructive value, and the social arrangements for members and ladies proved to be of an outstanding character. Buxton was a happy choice for the location of the Conference, which was organised by the Sheffield and District Branch of the Institute and the spirit of friendliness and co-operation, which was everywhere in evidence at this meeting, together with the interest displayed at the various sessions and works visits augurs well for the continued progress of the Institute.

Apart from Council and Committee meetings, which were held during the afternoon of June 10th, the Conference began in the evening of that day when members and their ladies were welcomed by the Mayor and Mayoress of Buxton, the Duke and Duchess of Devonshire, at a Reception held at the Pavilion, at which His Grace, in a short speech, wished all concerned with the Conference a happy and successful time spent in Buxton and Sheffield and their environs. The President of the Institute, Mr. Colin Gresty, responding, expressed thanks for the manner in which the Institute had been received.

Annual General Meeting

The business meeting was held in the Ball Room of the Spa Hotel on the morning of June 11th, the retiring President, Mr. Colin Gresty, being in the Chair. Annual reports of the Council and of the Technical Council were received, which indicated the amount of work necessary to maintain an Institute of this kind in a healthy condition. The balance sheet and statement of accounts to the end of 1951 were also presented, from which it is apparent that the membership continues to increase.

Presentation of Awards

At a Council meeting held earlier in the year, resolutions were adopted for the 1952 medal awards the presentation of which were made at this meeting as follows :—

E. J. Fox Medal—Presented to Mr. A. E. Peace in recognition of the work he has done for many years in improving foundry technique, particularly in the malleable ironfoundry industry, and especially for his distinguished work as Chairman of the Technical Council and leader, therefore, of the Institute's technical investigation work.

Oliver Stubbs Medal—Presented to Mr. H. G. Hall, in recognition of his services by imparting knowledge to his fellow members on the practice and theory of founding in a series of papers extending over the period 1930 to 1949 and of his contributions to the technique of the malleable cast iron industry.

British Foundry Medal and Award—This medal and prize of £10, which may be given annually by the Council to the author of the paper adjudged to be the best presented to the Institute during the preceding year, was presented to Mr. K. H. Wright in recognition of the excellence of his paper on chilled roll manufacture published in the recent volume of the Institute's Proceedings.

Meritorious Services Medal—Presented to Mr. John Jackson of the Lancashire Branch in recognition of his devoted service to the Institute in general, and to many individual members in particular, over a period of 30 years.

Diplomas—It was announced that the Council had awarded diplomas for the following papers presented at branches as detailed below : Mr. S. L. Finch, for his paper " Process Planning in the Steel Foundry Industry " presented to the Tees-Side Branch ; Mr. J. Gorman, for his paper "A Cross-section of a Non-ferrous Jobbing Foundry " presented to the Scottish Branch ; Mr. E. J. Brown, for his paper " Castings to Resist Abrasive Wear " presented to the Lancashire Branch ; and Mr. D. F. B. Tedds, for his paper " Experience with the Investment Casting Process " presented to the Birmingham Branch.

Election of Officers

Dr. C. J. Dadswell was elected President for the year 1952–3 and in a few well chosen words Mr. Colin Gresty, the retiring President, invested him with the chain of office. The Senior and Junior Vice-Presidents nominated by the Council, Mr. E. Longden and Mr. John Bell, respectively, were elected unanimously at this meeting. The following members were elected Members of Council, to serve for two years : Dr. A. B. Everest, Mr. H. G. Hall, Mr. R. L. Handley, Mr. A. E. Peace, and Mr. R. C. Shepherd.

Presidential Address

In the course of his address, Dr. Dadswell said that we were mostly conservative by nature and, in consequence, it took time for old habits to change and new ideas to develop. One sometimes disagreed with the widely held opinions of others and he hoped to put in proper perspective certain things which he did not think were

yet thoroughly understood, nor, indeed were they being approached with an open mind. His address was concerned primarily with "a sense of proportion."

This line of thought had its origin in a question at a recent Foreman's Training Course, an answer to which was not possible in the time available. A foundry was described in which a somewhat difficult casting had been made in small quantities not reaching three figures per day by skilled moulders, with considerable physical effort on their part. Eventually by some modification to the moulding technique and, more particularly, to the organisation of the work, and by the addition of some mechanical equipment of a relatively inexpensive nature, the output, with fewer and less-skilled men in the team, increased to ten times as much per day. One of the questioners was worried about the effect of mechanisation on the operators, in that the change had deprived the skilled moulder of skilled work, even though he was assured that the displaced moulders were transferred to alternative work where their skill was still required.

Dr. Dadswell felt that there were several lessons to be learnt from the analysis of this question and answer. He thought it wrong to assume that mechanical aids to production, simple or comprehensive, necessarily made those who operated them unhappy when they were not able to exercise their original craftsmanship. Many authorities on mass production had shown that their workers were not inevitably unhappy. That was in agreement with his own observations, providing that the conditions were such that the operators were able to work steadily and with a physical exertion that was not injurious to health.

He emphasised that mechanical aids had existed throughout the ages and modern mechanisation was only the application of the simple mechanisms which we were taught as fundamentals of applied mechanics. They were, however, applied in varying degrees, and often with power operation rather than manual operation.

In implying that castings could be made largely with unskilled personnel, he felt that members would regard him as contradicting both the sentiments expressed by previous holders of his office, on the subject of craftsmanship, and the efforts of the Institute in its encouragement of the craftsman. He believed, however, that what he was trying to express was completely in keeping with the motto "Science hand in hand with Labour." As foundrymen, their primary objective was to make good castings, castings which would hold their place with the products of competitive industries and would enable the users of castings to make their final products economically attractive to their own customers. If, therefore, to meet those demands it was necessary to use labour which was not trained to do a hundred and one skilled jobs, but to become specialised in doing a few, it should not be assumed that such labour was unhappy. It had been proved in other trades that the case was otherwise and that the worker's economic standard could rise because he participated, through his increased productivity, in a greater contribution to the total quantity of goods available for the use of mankind.

It was Dr. Dadswell's belief that, in spite of mechanical aids to production and the removal of the need for skill in the operators of the mechanical devices which gave quantity production, or even which helped the work of the skilled moulders, there would continue to be a need for skilled craftsmen, and he claimed that what he had said was not incompatible with the policy of the Institute. There would remain a need for craftsmen for work of accuracy and in small quantity which was dependent on the skill of the individual.

He referred briefly to the upgrading of operators from one skill to another, as was practised in America, and suggested that modern educational trends might leave much less time in which to train an all-round craftsman under the apprenticeship system, and might eventually bring about a system in which a worker developed from stage to stage in specialisation within crafts after the age we now expect him to become fully qualified.

Of the jobbing foundry he thought it much more difficult to improve the economic conditions for owner and worker unless it was tackled in just as analytical a way as when embarking on series production. There were many so-called jobbing foundries with enlightened ideas, but there were still many where the outlook could be changed with advantage. Logical thought could be applied to it just as much as in any other foundry. Jobbing foundries would train the craftsmen of the future and would absorb those who had been trained.

In conclusion, Dr. Dadswell expressed the view that many types of skill, simple but specialist, comprehensive and of craftsmen, were needed to make the wide range of foundry products, and suggested that we should accept those different types of skills rather than be afraid that one was replacing the other.

Edward Williams Lecture

There was a short break after Dr. Dadswell delivered his address, following which a large and appreciative audience gathered to hear Professor R. J. Sarjant, O.B.E., D.Sc., deliver the 1952 Edward Williams Lecture on the subject "Fuel and Metals." Fuel is so intimately associated with metals, especially in the foundry industry, that it was particularly appropriate that Professor Sarjant, who occupies the Chair of Fuel Technology at the University of Sheffield, should have been invited to lecture on so important a subject. Professor Sarjant was awarded the O.B.E. in 1945 in recognition of his work for fuel efficiency, and he was the Melchett Medallist of the Institute of Fuel in 1950. In addition to fuel engineering, however, he has achieved a considerable reputation in the fields of metallurgy and of refractory materials, and a great number of members attending this meeting had been looking forward with more than ordinary interest to a really informative lecture. That they were not disappointed can be appreciated by reference to some main features of his lecture given elsewhere in this issue.

Social Events

In addition to the Reception at the invitation of the Mayor and Mayoress of Buxton to welcome members and ladies, the social arrangements were of a very high standard. The most outstanding of these was the Annual Banquet, which was held at the Palace Hotel, in which over 550 participated. Preceding the Banquet, the President and Mrs. Dadswell received members and their guests. At this function, the toasts following that of The Queen included the Corporations of Buxton and Sheffield, proposed by Mr. Colin Gresty, the Immediate Past President, and responded to by the Mayor of Buxton, the Duke of Devonshire, M.C., and the Lord Mayor of Sheffield, Alderman Peter Buchanan, J.P.; the Institute of British Foundrymen, proposed by Mr. T. H. Summerson, J.P., Chairman of the British Steel

Founders' Association, and responded to by the President of the Institute, Dr. C. J. Dadswell; and the Guests, proposed by Mr. F. A. Martin, O.B.E., President of the Sheffield Branch of the Institute, the response being by the Master Cutler, Mr. Geoffrey M. Flather. The final toast was to Mrs. Gresty, the wife of the Immediate Past President, and in recognition of the support given to her husband during his term of Office, a presentation was made to her as a reminder of the occasion. Other functions at Buxton included attendance of members and their ladies at a performance at the Buxton Repertory Theatre, or a Film Entertainment at the Palace Hotel, after which both parties joined in light refreshment at the Palace Hotel.

On the final day, apart from a Dinner-Dance in the evening which was held at the Palace Hotel, Sheffield and its environs was the centre of interest and at a Luncheon at the City Hall, the Lord Mayor and Lady Mayoress extended a welcome to members and their ladies.

The arrangements made by the Sheffield and District Branch, who had the honour of organising this Conference, were of a very high order and the various Committees responsible can be congratulated on the success which attended their efforts. There can be no doubt that this Conference will provide happy memories for those who participated over a great number of years, certainly those responsible for future conferences will have difficulty in maintaining the high standard set on this occasion.

Works Visits

As is usual, works visits played a very important part in the success of the Conference in that they provided members with an opportunity of visiting other foundries and so widening their views and adding to their experiences. Sheffield and district offers exceptional facilities for this purpose, and during both morning and afternoon of the last day of the Conference visits were made to the alloy cast iron mechanised foundry of Sheepbridge Equipment, Ltd.; the non-ferrous and general steel foundries, including centrifugal casting and cement sand moulding, at the David Brown Foundries Company; the large steel foundries of Hadfields, Ltd.; the large jobbing foundries and repetition foundries of Newton Chambers and Co., Ltd., iron foundries for general engineering castings, including rolling mill castings, and a mechanised foundry for the production of ingot moulds at Brightside Foundry and Engineering Co. Ltd.; the steel foundry at Edgar Allen and Co. Ltd.; the large steel foundries and mechanised foundries for repetition work at the English Steel Corporation Ltd.; and the general and mechanised foundries of the Osborn Foundry and Engineering Co. Ltd.

It was necessary for members to make a choice in keeping with their individual wishes, as visits during the morning and afternoon respectively, were arranged simultaneously, but it is a pleasure to record that all the visits were well attended and it can still be said that members are enthusiastic over good work efficiently performed. It is good to know that there are enterprising firms that open their works for these visits, and officials that devote so much time to assisting the development of the foundry industry, it is an excellent method of combining theory with practice and the intimate discussions which take place at these works visits are usually of mutual benefit. Quite apart from the official words of appreciation that were voiced at the time, the expressions of appreciation by individual members would, in no small measure, compensate the works officials concerned for their efforts in making these visits the real success they were.

Technical Sessions

Fifteen papers were presented at this Conference together with two reports and, apart from the exchange paper from the American Foundrymen's Society and the Report of Sub-Committee T.S.35 of the Technical Council, which were presented at a session held during the afternoon of June 11th, all papers were presented during the morning and afternoon sessions on June 12th. Three sessions were held simultaneously in both the morning and the afternoon; it was, therefore, necessary for members to concentrate on those subjects of particular interest to them. The subjects discussed covered a considerable range and maintained a reasonable balance between theory and practice. Here it is only possible to summarise some of the main features of the work presented.

ROLE OF THE RESEARCH FOUNDRY UNIT

By G. A. Lillieqvist

Efforts have been made from time to time to define research, to differentiate between fundamental, scientific, applied and industrial research, but the author makes no attempt to discuss the merits of the several kinds of research, as the methods used to solve foundry problems are not of primary concern, the end result is the more important aspect. In general, fundamental research is carried out by universities and various research foundations, while applied research is being concentrated upon by industry, and in this paper, which is the official exchange paper of the American Foundrymen's Society, the author discusses the contributions research has made to the foundry industry.

Mr. Lillieqvist, who is the Director of the American Steel Founders' Research Department, describes the organisation of his department, which is divided into three sections—foundry, melting, cleaning and finishing—and outlines the activities of each section, the method of classifying research laboratory projects, and the method of reporting on research projects. In emphasising the utilisation of research in production, he submits that merely supplying the works with written reports is insufficient; new methods, processes and applications must be discussed and there is a contact man at each of the plants with whom the various subjects can be discussed. The contact man in turn reports the findings to the respective works managers and, if favourably accepted, plant experiments are outlined. The contact man co-ordinates the various experiments and reports the results to the respective works manager and the research director, who in turn reports the findings to the vice-president in charge of the manufacturing division. A decision is then made whether or not the new process should be adopted as standard practice.

After briefly referring to the finance and committee work in connection with the department, and to the research laboratory layout, the author deals with a few aspects of the results of research, and of these particular reference is made to the influence of temperature on fluidity. Experiments have demonstrated that, from a practical viewpoint, the mould-entering temperature is the most important factor in the control of the property "fluidity." The temperature of liquid steel in a 30-ton

ladle, at a point approximately 9 in. above the nozzle, was determined from the beginning to the end of the pouring operation at a basic open-hearth plant. It is noteworthy that the temperature of the steel increased at the end of the pour. This gives valuable information, as it has always been claimed that light section castings should be poured at the beginning of the heat.

The phenomenon of hot-tearing in steel castings is complex as so many factors are involved, such as the chemical composition of the steel, the mould-entering temperature, and, probably more important, the proper adjustment of the sand- and core-mixes. At the present time, only external hot-tears have been studied by the author's concern, and a suitable test-casting to evaluate the sensitivity and reproducibility of hot-tearing has been developed. Results given from tests made show the relationship between hot-tear rating, steel-entering temperature and sulphur content.

Welding electrodes for steel castings and inspection methods are discussed in the paper and experiments carried out with a view to obtaining higher physical properties described. The work of the British Cast Iron Research Association on the use of cerium in cast iron has been followed with great interest in America, and experiments with additions of cerium and Mischmetals to steels of differing carbon content show considerable improvement in ductility and impact value, whether in the normalised condition or after being quenched and tempered.

The problem of developing an alloy which will act both as an efficient deoxidiser and desulphuriser has been under consideration for many years, especially for acid open-hearth and acid electric-furnace steels. Progress has been made and it is likely that such an alloy will be commercially available in the not-too-distant future. Various encouraging experiments have been made with sodium additions, but, due to the hazard involved, more experimental work is necessary. Other alloys in various combinations which have exhibited great promise are the calcium/manganese/aluminium variations. A typical alloy with which the author has had some success, both in basic and acid practices, has the following approximate percentage composition :—calcium 20, silicon 45, and aluminium 12. A decrease of approximately 5 points in the sulphur content is being obtained with this alloy combination.

Other aspects discussed in this very interesting paper include the "C" or shell-moulding process, phenolic resins, carbon "pick-up" from cores, and service-failure investigations.

FLOW OF METAL

Report of Sub-Committee T.S.35 of the Technical Council

This sub-committee was formed to study the flow of metal into moulds using colour cinematography or other suitable means for recording purposes. In carrying out this work full consideration was given to the investigation into the influence of the effects of gate design in steel casting by Fry and Baker, and also to the work of Swift, Jackson and Eastwood with liquids in Lucite moulds. A film previously made by the Meehanite Research Institute on metal flow patterns into open-top moulds, and Tedds' method of using mercury in glass sided plaster of paris moulds, were also studied.

It was early realised that, within certain limitations, the use of fairly high-speed photography with a cine camera would provide the type of record best suited for instructional purposes, but that certain moments in the sequence of tests could be photographed statically in order that particular point might be raised for special discussion, without damage to the film record.

A film was prepared and was shown at this session. The film does not cover all aspects of good gating practice, nor of all the various types of ingates used in the foundry; this would have been impossible within the limits of normal cine viewing and was not attempted. The film was presented as a practical contribution to the subject of gating and the pouring of metal, rather than as a basis for theoretical discussions into such subjects as the hydrodynamics of fluid-flow velocity, frictional retardation, gravity and pressure effects, viscosity or effect of surface tensions. From the practical point of view the film was both interesting and informative and as a result of this work, it is likely that further investigations will be made on the flow of metals with the aid of cinematography.

STRENGTH, STRUCTURE AND COMPOSITION OF UNALLOYED GREY IRON

By H. T. Angus, Ph.D., M.Sc.

A good deal of work has been published in recent years relating the composition to the strength and properties of cast iron, but the present paper is concerned primarily with the presentation of an orderly summary of existing knowledge in such a manner that the average foundryman can make ready use of it in his day-to-day work.

The basis upon which the author builds his discussion is the carbon equivalent value :

$$C.E. = T.C. + \frac{Si + P}{3}$$

This formula is an expression of the effect of silicon and phosphorus in lowering the carbon eutectic figure by approximately $0{\cdot}3\%$ for each 1% of silicon and phosphorus present. Only unalloyed and non-inoculated irons are considered.

The characteristic mechanical properties of cast iron are largely dependent upon the amount of graphite present, and as the composition of the iron with relation to the eutectic value to some extent controls the amount of free graphite that is present in a casting, an expression of this type may be expected to give some indication of the mechanical strength of the iron. Although there is quite a substantial scatter in the results, the probable tensile strength can be predicted with some degree of certainty. The author shows graphically the order of scatter to be expected when representing the tensile strength against composition on a standard 0·875 in. dia. bar, and as a result of a considerable number of test figures, he shows a series of curves relating the probable tensile strength obtainable for all five British standard test-bars in relation to their composition as determined by the carbon equivalent value.

A similar series of curves is also shown for the transverse strength. It is stated that the ratio between transverse rupture stress and the tensile strength is reasonably close for all bars between 0·6 and 1·6 in. dia., and varies only with the tensile strength itself. A series of curves of the reduction of strength with section is also shown for five of the irons which meet B.S.1452 (1948).

Although the properties noted above do bear some relation to the composition, as expressed by the carbon equivalent value, no such simple relationship can be

adduced for the Brinell hardness figure. Any attempt to specify hardness together with other properties must be done with a full knowledge of the composition likely to be employed, the size of the casting to be tested, and the position at which the hardness test is to be taken. Nevertheless, for closely defined conditions the hardness figure can bear a relationship to the tensile strength.

The resistance of an iron to shock bears no relation to the carbon equivalent value. For low phosphorus irons, shock resistance increases generally with tensile strength. Increasing the phosphorus content, however, lowers the shock resistance even where similar tensile strength is obtained.

Regarding the relationship between composition and structure the foundryman is particularly concerned in producing (or avoiding) three main types of structure: soft irons; strong, machinable grey irons; and mottled, chilled or white irons. Difficulty is experienced in devising a simple means of determining into which group a particular iron will fall when used in a casting, due to the many variables that affect the microstructure. In order to make even an approximate attempt to evaluate these variables, some simplification is necessary and the two most useful simplifications in the author's experience are the series of diagrams first proposed by Uhlitzsch and Weichelt and the figure put forward by Sipp and modified by Angus, Dunn and Marles, which are reproduced in the present paper, the latter being based upon five types of structure shown in photomicrographs.

The chief difficulty in using these diagrams is that of interpreting the results in terms of foundry practice, since it is quite impossible to make any allowance for section size except on the basis of standard sections and it is necessary to interpret the results likely to be obtained in actual castings in terms of standard conditions. Schneidewind and McElwee use the term "equivalent diameter" to express the cooling rate of a given casting section, and the author regards this as a convenient method of expressing cooling rates for castings and discusses at some length the main factors involved in dealing with cooling rate.

PRODUCTION OF INGOT MOULDS BY SANDSLINGER IN A MECHANISED FOUNDRY

By J. Raymond Jones

Cast iron ingot moulds are essential to the production of ingots in the steel works, and their production as described by the author is particularly interesting because it is concerned with the procedure in a new mechanised foundry, recently put into operation at the Landore works of Richard Thomas and Baldwins, Ltd., designed especially for the making of ingot moulds. This foundry has been built to take care of the major requirements of the Abbey, Margam and Port Talbot works of the Steel Company of Wales, and the Ebbw Vale, Redbourne, and the West Wales works of Richard Thomas and Baldwins.

The foundry is made up of three parallel bays, comprising a charging bay, tapping and ladle bay, and the main production bay, the latter being 600 ft. long and 56 ft. 6 in. wide. Midway between the charging bay and the ladle bay are installed three cupolas, each being worked in turn and so allowing a cold cupola to be repaired each day. The internal diameter of each cupola is 5 ft. 11 in. and the slag hole is 22 in. above the tap hole. There are two rows of tuyeres, five in each row. Slag is led into a slag pot which is pulled to and from position by a winch at the back of the cupola, and when solid, loaded direct into wagons to go to the tip. About 25 ft. above the floor level is the cupola stage, from which the charging of the cupola is controlled. The average melting rate is 12 to 14 tons per hour and the cupolas work in two shifts and are capable of turning out 250 tons per day.

A continuous sand mill is installed, it having been considered that a continuous mill had many advantages over a batch mill. In the course of the discussion, however, Mr. Jones stated that batch mills were available in reserve. The mill installed is a Coleman continuous mill having a maximum capacity of 25 tons per hour. Sand is discharged from the sand mill and by a series of conveyor belts delivered into various hoppers over Sandslingers. Fed to these machines, sand can be thrown into moulds at the rate of 10 to 12 tons per hour within a radius of 15 ft. of each machine, and it is adequately rammed.

The core is carried on a core-bar, which is a hollow tube of cast iron, suitably vented, and which follows the shape of the inside of the mould, allowing 4–6 in. of sand all round; the bar is permanently bolted to the centre of the bottom box. It is wrapped with straw rope and the surface slurried over with a mixture of blacking and sand before being placed in the Sandslinger ramming pit.

There are eight drying ovens, four at each end of the moulding bay and directly opposite the Sandslingers and outside the gantry track so that only the bogie rails project into the working bay and thus floor space is saved. From the drying ovens the parts are removed to the casting area and assembled, closed and cast. Reference is made to the stripping of the subsequent castings, to their cleaning, and to the laboratories and records department.

The main controlling factors in the design of this new foundry were to build a foundry capable of producing 1,000 to 1,200 tons of ingot moulds weekly; to design a foundry in which hard physical work was reduced to a minimum; and to implement the "Garret Report" by building a foundry that was light and airy, and which would be kept clean and free from dust, giving working conditions as near perfect as possible; the result seems to be an achievement of a very high order.

METHODS EMPLOYED IN THE PRODUCTION OF HEAVY IRON CASTINGS

By J. Richardson and C. F. Lawson

This paper, which was introduced by Mr. Richardson and presented by Mr. Lawson, was particularly well received as an excellent example of the practical work of the foundry. In it the authors have presented a variety of examples showing the general principles and methods employed in the making of heavy castings for steel works plant and equipment for rolling mill and forge, but which are applicable to the production of general heavy iron castings. They show some of the advantages to be gained by the "scientific approach," and indicate the further lines of research which would be of direct assistance to the practical man. They assert that there is no substitute for practical experience, even if it is only used to determine what is and what is not of importance on a particular job. And there was general agreement with their view that reliable craftsmanship is the only medium through which technical achievement can be brought to fruition.

Where two castings are made successfully by apparently different methods the authors suggest that the main principles have been observed, that it is merely the trimmings that are different. In making a decision, the task is to subject the methods used to closer observation and analyis, determine the main factors involved, evolve means for their measurement and control, and then apply personal knowledge together with common sense. The facilities available in any one foundry will decide the method of construction of a particular mould but definite principles decide the fundamentals, such as the method of gating, feeding arrangements and type of metal to be used.

When foundry problems arise, the authors emphasise the need for honest analysis. On such occasions emotional stress is apt to preclude sound judgment; it is therefore very helpful to be able to approach the problem systematically, and by factual elimination to narrow down the field of possibilities. Naturally all concerned will have many suggestions which, surprisingly, nearly always arise out of "the other fellow's" part or operations in the job. At this stage honest analysis poses the following questions:—(1) Is one looking for the reasons for the failure and thereby the means to future success; or (2) Is one merely looking for someone to blame? Depending on the answer to this first question will be the success of further enquiry and analysis.

As an example of the analytical approach to general principles and problems, the authors present a method of general analysis of foundry factors and of production factors. The general foundry factors are concerned with (1) organisation and administration, planning and control; (2) layout and equipment; (3) mould and core materials, preparation and control; (4) metallurgy, melting, materials and control; and (5) training, welfare and control of operatives and staff. Production factors can be subdivided into craft operations subject to standard methods, for example, mould construction, coremaking and supporting, and venting of cores and moulds, etc.; and factors involving physical and chemical laws and requiring technical control, such as, mould and core materials, metallurgy, gating and feeding, and solidification and cooling phenomena. These production factors require almost the direct attention of the management and technical staff. The principles involved and decisions made are the direct responsibility, in most cases, of the foundry manager—the operator or craftsman working strictly to his instructions.

The remainder of the paper is concerned with methods used in the production of steelworks castings and, since these castings can rarely become repetitive, they can be classified as jobbing or general engineering work. The authors have not yet found any method of using unskilled operatives successfully on jobbing work, but by control of materials and application of certain principles they have considerably reduced many hazards which previously were regarded as part of the moulder's skill.

MANUFACTURE OF HIGH-QUALITY STEEL CASTINGS AT AN ECONOMIC PRICE

By J. J. Dewez, Ingenieur Civil des Mines, A.I.Br.

The main purposes of this paper are to substantiate the fields of application of steel castings and to extend their possibilities by fulfilling the requirements of modern construction. It is the Official Exchange paper from l'Association Technique de Fonderie de Belgique and was presented by M. Dewez in person. The factors which he regards as the most important, and which should be studied in relation to the manufacture of steel castings, are discussed under five headings as follows:—

(1) Co-operation between the drawing office, engineer and foundryman at the design stage.
(2) The question of quality of castings produced in every respect, viz., internal and external soundnesses, composition and heat treatment of the steel, dimensions, shape and machining allowances.
(3) Control of every operation during and after manufacture from the methods department to the final checking.
(4) The question of the cost of all operations.
(5) The human aspects of the question in relation to the quality of the men employed.

The first step in the manufacture of high quality steel castings at a competitive price is the designing of the casting itself. Few draughtsmen have an accurate knowledge of patternmaking, moulding, coremaking core-setting, closing or pouring operations. The physical and chemical laws governing the interaction between sand and metal, the solidification of the steel and the cooling of the casting must also be very well understood by the designer. At the works with which the author is associated, all the draughtsmen in the drawing office of the steel foundry must know all these important principles and must spend part of their time in the methods department, the inspection department and the non-destructive testing department of the foundry; they are then better equipped to design steel castings so that their production is simplified, quality improved and cost reduced. They are also in a better position to suggest to customers changes in design likely to enable the foundry to produce more satisfactory castings.

In addition to drawing office co-operation, the author emphasises that quality must be the first consideration of the modern and progressive steel foundry. The quality of steel castings depends so much on the care of everyone concerned that it is necessary to survey, control, and check every operation by the best possible method in order to reproduce more accurately the conditions which have proved by experience to give the best results. It is suggested that steel castings should be rough machined before delivery to customers, and for this reason the steel foundry should be equipped with machine tools. The parts of the castings where defects are most likely must, for ordinary steel, be rough machined by the foundry before annealing, and before final treatment, for special steels, in order that such of the defects disclosed as are repairable can be mended.

The reports of the methods department must be so made that every trouble found during the manufacture of any steel casting, and every customer's complaint can be made available to all concerned when a similar job is to be made, even after many years. The choice of the correct chemical composition of carbon and alloyed steels and of the correct heat treatment to apply in order to give the metal the physical properties necessary to withstand the conditions in which the steel casting is going to work is very important, since it is primarily by quality that the progressive steel foundry will be successful in supplying the needs of modern engineering.

The author gives several examples of job layout, and feeding and risering techniques, and discusses many other

factors that are now associated with modern steel foundry practice. He concludes with the belief that, with improvements continuing at the same rate as during the last 10 years, steel castings will be considered the most reliable and economical products for many purposes.

PROBABLE TRENDS IN BRITISH STEELFOUNDRY PRACTICE

By F. Cousans, F.I.M.

There is a real progressive spirit in the steel foundry industry and in this paper the author considers practices likely to be employed in the future in this country. On steelmaking, he states that the basic electric furnace and the acid, side-blown converter processes are in most general use. The open hearth (acid and basic), and high frequency furnaces are also used, the latter largely for special steel casting production including heat- and corrosion-resisting qualities. Owing to the steel scrap shortage, which is likely to persist for a number of years, those using the electric process are likely to be compelled to use the basic process, but when sufficient good scrap becomes available, many will change to the acid process. The high cost of electric power is a serious problem to the user of electric-arc processes and more extensive use of the oxygen lance will be made for the elimination of carbon, silicon, and phosphorus. This will result in a reduction of the time taken for the first part of basic electric heats and a saving in power costs. It seems, therefore, worthwhile to concentrate on the second part of basic electric heats, to see what can be done to produce, more quickly, reducing slags. In view of the success of the Perrin process, he suggests that if means could be found of producing, and pouring into the basic furnace, synthetic slags of suitable composition to heats of steel ready for final sulphur reduction and deoxidation, the time needed for the second part of the process could be greatly reduced. Among other developments suggested, larger capacity transformers on electric furnace plants, the use of furnaces with swinging roofs, which permit of basket charging, and rammed roofs are likely to receive more attention and trial. The storage of materials for steelmaking under cover offers many advantages, and in mechanised foundries, producing carbon steel castings, it would be advantageous to have steel "on tap" thus permitting continuous casting. The use of a holding furnace is valuable where continuous casting is desired. The present shortage of good-quality melting coke, and its cost, are seriously handicapping the side-blown converter process. The use of the hot- or warm-blast cupola, and of an oxygen-enriched air blast are likely to be developed and applied to cupolas used for producing metal for conversion in side-blown converters. As mechanisation of foundries extends, the steelmaking sections will be regarded as service units, producing when and what the foundry requires and working in the direction of smaller heats at very frequent intervals.

Mr. Cousans makes many valuable suggestions on sand practice and for speeding up moulding. He is of the opinion that the "C" process of shell moulding is capable of great development and application to steel casting production, but, to obtain the maximum advantages it will be necessary to have a proper set-up, with full mechanical aids to assist each operation. With regard to cleaning and dressing, the greatly increased use of the Hydroblast is to be expected, together with that of the split-roof type of Wheelabrator and of the barrel or drawn type Wheelabrator, for the initial cleaning of castings. Many fettling and dressing shops could make much more use of mechanical aids, such as fettlers' benches, lifting facilities, conveyors, burners, turn-tables, etc., with advantage. The mechanical handling teams which recently visited the United States have demonstrated the great use and attention given to handling devices and equipment in many American organisations, and very great improvements and economies are possible in this connection in this country.

In view of the progressive outlook now evident among steelfounders, Mr. Cousans predicts that much attention will be given in the future to production control and planning. On the subject of training schemes he suggests there should be an interchange of apprentices in the patternshop and foundry sections, but while agreeing that much is being done for apprentices, much more is required to be done to improve the standard of supervision if the present progressive outlook among steelfounders is to be maintained.

SAND-CAST BERYLLIUM-BRONZE

By L. Grand

Beryllium-bronze provides a link between the general properties of the bronzes and of steel. It pours and casts particularly well, it can be made very hard by heat treatment, it is easily machinable in the as cast or annealed state, and it has high mechanical strength. Other valuable properties of this material include high heat- and electrical-conductivity, non-magnetic property, low coefficient of friction on steel, high abrasion resistance, absence of sparking when struck. It is, therefore, rightly regarded as one of the high-grade bronzes, but developments in the use of this material are somewhat hampered by its high cost. In this paper, which is the Exchange Paper from l'Association Technique de Fonderie, the author elucidates some of the properties of beryllium-bronze, believing that it would be more widely used if it were better known.

The percentage composition of the beryllium-bronze of practical interest is: 97·2 to 97·8 copper, 1·9 to 2·3 beryllium, and nickel or cobalt 0·3 to 0·5. The nickel or cobalt is not essential in the particular case of castings, since these constituents have the sole object of preventing grain coarsening as a consequence of recrystallisation in the heat treated alloy. The effect of small additions of boron, zirconium, or titanium on the structure is discussed. From a casting point of view such important factors as castability, pouring temperature, shrinkage, cracks, draws and gassing are considered. On the subject of the oxidation of this bronze in contact with air during the time of melting, the author refers to precautions that should be taken, particularly when finely divided scrap metal is to be melted, to prevent loss of beryllium. Turnings and small croppings should be plunged into a bath of molten metal, preferably with a molten flux covering the bath. A suitable flux is barium or sodium chloride. The latter, however, emits fumes which may be troublesome in the foundry. The use of a flux not only enables beryllium losses to be reduced, but aids degassing of the metal.

The mechanical strength characteristics of beryllium-bronze depend on the composition, purity and structure of the alloy, and also on the conditions of heat treatment and casting and the author discusses the influence of

composition, of impurities, and of metal structure, and, particularly, of casting conditions and heat treatment on the development of mechanical properties.

PRODUCTION OF MANGANESE-STEEL CASTINGS

By F. Cousans, F.I.M., and W. C. Meredith, M.B.E.

The authors introduce the subject of this paper with a brief history of manganese steel, which includes accounts of Sir Robert Hadfield's experiments, early production methods and typical designs of castings, and then proceed to give in detail present-day methods used in the foundry for producing castings in this material. The composition of manganese steel now generally used for casting production contains 1·0 to 1·4% carbon, up to 1·0% silicon, low sulphur, 0·14% phosphorous, and 10 to 14% manganese. Considerable tonnages of the steel are still made by adding molten ferro-manganese to low-carbon steels, made in either bottom-blown or side-blown converters. The ferro-manganese may be melted in crucibles, cupolettes, reverberatory furnaces, or in small, basic electric furnaces. Precautions are necessary to prevent excessive loss of manganese during the melting of the alloy. This steel is also made in the electric furnace by the addition of ferro-manganese to charges of carbon steel. Quite considerable tonnages of manganese steel are now made in basic electric furnaces from recovered scrap, the melting of which was previously a serious problem.

The authors discuss the moulding materials and washes used, and particular attention is given to the special techniques developed for producing sound castings in this material. They deal with feeder heads pouring, knocking-out and quenching, and conclude with mould layouts of a considerable number of important castings, such as clamping ring segments for wet-grinding plant, a double-eyed hammer casting for a crusher, a grid plate casting for a cement mixer, a ball-mill wrapper liner casting, a fixed-jaw face for a stone breaker, a toggle plate for a stone breaker, dredger bucket lips, diamond-pointed bucket-teeth, chain links, a swing hammer for a pulveriser, a toggle groove for a double-toggle jaw breaker, crusher-jaw castings, tramway crossing castings, etc.

GAS REMOVAL FROM MOLTEN ALUMINIUM ALLOYS

By A. W. Brace, A.I.M.

From the earliest days of aluminium founding, the appearance of porosity in aluminium castings has been a matter of concern to the practical foundryman, but with accumulated experience of the technique of casting aluminium and research into the mechanism of solidification, great strides have been made in establishing principles of mould design and feeding methods, thus avoiding local shrinkage. The other main type of porosity met with is more commonly referred to as "pinholing," and this has given rise to a large amount of research work dealing with its elimination or control and in this paper the author reviews the work that has been carried out on the problem of removing dissolved gas from molten aluminium alloys. He surveys the mechanism of gas absorption and removal, including sources of hydrogen, mechanism of absorption, factors affecting the amount of porosity and its distribution, and conditions for the removal of gas from the melt. Consideration is then given to the application of this knowledge for the production of castings under normal foundry conditions. It is shown that there are two methods used for the elimination of gas porosity: the introduction of an organic chloride, releasing chlorine usually in conjunction with a grain-refiner, and the use of a flux either by itself or in conjunction with nitrogen. An investigation made by the author and his colleagues, under production conditions, is described. It is shown that the application of a chloride can result in shrinkage porosity of similar distribution to the more usual pin-hole porosity produced by removal of the residual gas normally present. Arising from this, a system of control is outlined in which the soundness of the metal is assessed microscopically. The standard melting technique recommended is the application of a flux prior to pouring. The author does not recommend the application of chlorine compound, except when the gas content has increased appreciably and then only for a time sufficient to treat all scrap in circulation. Work is already in progress for determining quantitative values for high and low gas contents, but more research is needed to establish the effect of alloying elements on the absorption of gas and its solubility in molten metal.

SOME EFFECTS OF MAGNESIUM ON THE FORMATION OF GRAPHITE IN A SOLIDIFYING CAST IRON

By I. C. H. Hughes, B.Sc., A.I.M.

In view of the development of spheroidal-graphite cast iron, in recent years, as a result of a great deal of research, it is not surprising that further information concerning this development should be presented in a paper at this Conference. In this case the author briefly reviews the main work on the subject and the hypotheses published to date, and reports the results of experimental work designed to provide information on the process of solidification of a cast in both the magnesium-containing and magnesium-free condition. The conclusions drawn from the experiments relate only to the effect of magnesium. They show that the addition of magnesium to cast iron of slightly hypoeutectic composition appears to have three main effects, although it is not known to what extent these are interdependent. They are: (1) depression of the eutectic temperature, with an accompanying increase in the number of centres of eutectic crystallisation; (2) change in the form of graphite particles to spheroidal, with the resulting essential change in growth mechanism, due to the formation of an austenite envelope around each spheroid; and (3) increase in the tendency of the eutectic liquid to solidify as iron-carbide eutectic and a decrease in the tendency to form new graphite particles of any shape after the beginning of the eutectic reaction.

The author states that inoculated flake-graphite and spheroidal-graphite cast irons appeared to have very similar solidification sequences; in each, the primary austenite dendrites appeared first, followed by the appearance and growth of crystallisation centres in the liquid of highest carbon concentration, i.e., at the liquid-solid interface. The centres then grew to replace the whole of the remaining liquid. When inoculation was omitted, this made a small difference to the structure of the flake-graphite iron of high-graphitising tendency, and a very slightly decreased number of eutectic centres, each containing a slightly increased number of fine flakes, was observed. In the magnesium-containing iron, however, an appreciable decrease in the number of centres of eutectic crystallisation was observed, and

incomplete transformation of the liquid to graphite and austenite took place, possibly partly because of the reduced number of graphite particles. The last liquid solidified as the austenite/iron-carbide eutectic, which represents the smallest redistribution of carbon atoms on solidification (assuming a random distribution in the liquid): some of this carbide probably graphitised subsequently. Possibly because of uneven diffusion of carbon, the spheroids assumed an irregular outline during growth.

These conclusions may not be of general application, and much remains to be learned about the effects of composition changes, of other spheroidising elements, of interfering elements, and of inoculation, before the full mechanism of spheroidal-graphite formation is established. The findings are broadly in agreement with the conclusions of Dunphy and Pellini, but they differ in detail; for example, it has been shown that in inoculated magnesium-containing irons, the last liquid solidifies directly as austenite and graphite and that the solidification of the iron-carbide eutectic, with subsequent rapid graphitisation, occurs only when inoculation is omitted.

INTERNAL STRESSES IN CASTINGS

First Report of Sub-committee T.S.32 of the Technical Council

Internal stresses are those stresses which may remain in a casting after it has been removed from its mould. They arise during casting and subsequent cooling and do not depend on any continuously applied external source of stress. Their effects on the casting may be similar to those caused by stresses imposed from some external source, possibly arising during normal service, but the latter type of stress disappears on removal of the external source. Internal stresses are sometimes referred to as residual stresses and in general can be removed only by heat treatment.

The purpose of this report is to describe some ideas and the evidence on which they are based as a result of new experimental work, carried out by this Sub-committee, which, to some extent, developed from that carried out by Sub-committee T.S.18 and published in the 1949 Proceedings of the Institute. It is emphasised that the ideas presented depend on a relatively small amount of work so far completed on only a few types of castings. The conclusions must, therefore, be regarded as tentative.

Internal stresses in castings may be caused by (*a*) hindrance of contraction by the mould; (*b*) temperature differences within the casting; and (*c*) transformations in the solid metal during cooling. The characteristic defects arising from these sources of stress are summarised as follows: (*a*) sand effects lead to hot-tearing, distortion and plastic deformation at higher temperatures, the last of which may, in turn, cause internal stresses to form at lower temperatures; (*b*) temperature differences cause plastic deformation at higher temperatures, leading to internal stresses at lower temperatures and so, possibly, to cracking or distortion in the cold; (*c*) transformations causing volume changes are associated with internal-stress development and consequent cold cracking.

Preliminary results from experimental work so far carried out on a few different types of casting, and using various metal compositions, indicate that temperature differences are an important cause of internal stresses in castings, and that the stresses due to temperature-gradients in simple castings may be of a magnitude approaching the yield strength of the casting.

GRAIN REFINEMENT OF NON-FERROUS CASTINGS

By G. Swinyard, M.Sc., B.Sc., A.I.M.

It is generally known that grain refinement confers many advantages on alloys. The mechanical properties are improved and castings are less susceptible to leakage under pressure, and alloys which not infrequently crack when cooling in a cast shape are not so prone to this defect when the grain size is small. On the other hand fine grain is a disadvantage in those alloys which should have a high resistance to creep and in magnesium alloys which have been strongly chilled, since during subsequent heat treatment an extremely coarse grain would be produced especially in those areas where the original grain is finest. Yet the effect of grain size on non-ferrous castings is rarely discussed in foundry literature; in this paper therefore the author has assisted in a considerable measure in rectifying this omission.

Consideration of the grain size of an alloy is based on the structure which is revealed by macroetching and not upon the modifications which may occur in the microstructure. The method is essentially arbitrary since a grain size which would be regarded as fine in aluminium alloys would be coarse if found in magnesium alloys. There are two aspects of grain refinement: one is the actual reduction in the size of grain while the other embraces the conversion of columnar crystals to equiaxial crystals. The latter type of grain refinement depends essentially on the treatment of the melt before pouring. A reduction in grain size may often be obtained by lowering the pouring temperature of the alloy in question, although in the case of magnesium alloys the reverse is true. The use of chills is another method in common use for obtaining the same effect.

The author discusses grain refinement in relation to the alloys of aluminium, magnesium, and copper, and suggests that the advantages of grain refinement would repay further work on the subject.

RESEARCH ON ATMOSPHERIC DUST IN STEEL FOUNDRIES, WITH SPECIAL REFERENCE TO THE USE OF STATISTICAL SURVEYS

By G. M. Michie, M.A., A.Inst.P., A.I.M. and G. H. Jowett, B.A., F.S.S.

The health hazard associated with the inhalation of atmospheric dust arising during steel foundry processes has, for many years, been the subject of concern within the industry. Investigations carried out with a view to reducing and, so far as is possible, to eliminating the known risks have been directed along three main lines, namely, the prevention of dust generation, the prevention of its inhalation, and the reduction in the use of materials containing free silica. The growing appreciation of the importance of this field of investigation, and of the progress already made, was marked by the appointment in 1943, by H.M. Chief Inspector of Factories, of the Dust in Steel Foundries Committee, which has since issued two reports of great value, and which have served to draw attention to the difficulty of dealing with what is, in fact, not a single problem, but a complexity of related problems.

A very comprehensive programme of research is being conducted by the steelfounding industry, through its

research organisation, towards the removal of the dust hazard, but the authors of this paper do not attempt to describe in detail the various lines of investigation in progress, their purpose being to describe one particular aspect of the general problem, namely, the use and the interpretation of environmental dust surveys. Initial reference is made to dust sampling and estimation and to the potential importance of automatic methods. For the purposes of illustration, the results obtained from two environmental dust surveys in steel foundries have been subjected to detailed statistical analysis and are then discussed. The results show the influence on dust level of such factors as the local operational process, the day of the week and the time of the day. In conclusion the statistical considerations involved in the design and analysis of such surveys are discussed

GAMMA RADIOGRAPHY IN THE FOUNDRY

By R. J. Hart

The development of radioactive isotopes for medical, biochemical and industrial use is proving of immense value to the whole community. In this paper their use for inspection purposes in the foundry has outstanding possibilities and the author states that there is no reason why destructive testing should not be eliminated completely. At present only three isotopes are used for heavy industrial radiography, but these have outstanding possibilities, enabling industrialists to improve their products and to attain a standard of quality hitherto rendered impossible of achievement due to the "undetectable defect" factor. As an inspection tool, gamma radiography serves a two-fold purpose in affording the foundryman an opportunity to observe and improve his foundry technique, and has a distinct advantage to the purchaser, in that valuable machining time is saved, which was previously spent on castings that were eventually rejected. The author outlines these advantages of radiography for routine inspection of castings and is in no doubt that this method has come to stay and will eventually become standard inspection practice, as it is in the foundry with which the author is associated.

RECENT EXPERIENCE WITH BASIC- AND ACID-ELECTRIC STEEL

By L. W. Sanders, A.I.M.

This paper describes the change-over from a small basic-lined electric furnace for steel melting, run in conjunction with a Tropenas converter plant, to balanced production from modern, basic- and acid-lined electric furnaces. Particulars of the new plant are given, together with details of the linings, the melting process and degree of uniformity and reproducibility obtained. The change-over has resulted in a more even flow of metal through the shop, and a quicker turn-round of moulding boxes. The same quantity of steel is produced by reduced manpower in the same overall time. The author concludes that if the timing and procedure are controlled, there are no metallurgical difficulties in making acid steel for foundry use. If close control of scrap is maintained, acid steel can be produced having physical properties similar to, or only slightly inferior to, basic-electric steel. No claim is made that oxygen injection promotes cleaner steel by comparison with properly-controlled ore practice, but it does definitely facilitate faster throughput at lower cost. In the light of later experience, the author believes that a higher kVA rating in the basic unit would make for a more balanced combination. The basic-lined furnace installed is a 3-ton, 1,000 kVA furnace, while the acid-lined furnace has a capacity of 1½ tons and is also rated at 1,000 kVA.

THERMAL EXPANSION AND CONTRACTION OF COMPACTED STEEL-FOUNDING SANDS AND MOULD WASHES

By D. V. Atterton, M.A., Ph.D.

The expansion and contraction characteristics of moulding materials largely influence the formation of such casting defects as scabs, buckling and rat-tails, and together with the expansion characteristics of mould washes, are also important in mould-wash cracking. This paper describes an investigation of the length changes that occur during the heating and cooling of small, dried compacts of various moulding materials. For simple bentonite-bonded moulding sands, the expansion up to about 1,000° C. increases in the order zircon, olivine, silica. The expansions of zircon and olivine sands are regular, in contrast to the irregular expansion of silica sand. The expansion of loosely-rammed, low-density compacts of bentonite-bonded silica sand is small; it rises rapidly as the density is increased, then quickly falls to a low value, and further decreases slightly with further increase of density. Increase of binder and moisture contents in the "green" state both lead to a decrease in compact expansion. The theory proposed to explain these variations suggests that the expansion is controlled by (*a*) the thickness of the clay bond between the sand grains; (*b*) the presence of closed pores (which can be inflated by gaseous pressure) in the clay bond; and (*c*) the strength of the clay bond; this theory takes into consideration experimental results on the expansion characteristics of the bentonite bond and on the strength of the bond between the sand grains. Observed variations of compact expansion with sand grain-size merely reflect resultant variations in compact strength. No evidence of any influences of wood-flour or of organic binders on the expansion characteristics of silica sands has been found. The difference of expansion of a silica wash and a silica sand is shown to produce cracks in the wash; the effect is considerably accentuated when a silica sand is coated with a zircon wash. Casting defects caused by volume instability in the mould-material are discussed in the light of the results, which suggest that differential expansion between the facing sand and underlying sand is the prime cause of scabs.

New Company Formed

A new company has been formed for the purpose of granting licences throughout the world, under the Rudorff and other patents, for the application of the new process of electronic machining of materials. The process is of particular value for the machining and finishing of the harder materials and those which are exceedingly difficult to form by conventional methods.

The new company, Sparcatron, Ltd., has been formed by the Bath and Portland Stone Firms, Ltd., who also control Impregnated Diamond Products, Ltd., Gloucester —makers of the "Nevin" impregnated diamond tools already widely used throughout industry to grind tungsten carbide and many other hard materials. Laboratories for pure and applied research have been set up by Sparcatron, Ltd., at the Head Office and Works, Tuffley Crescent, Gloucester.

British Welding Research Association

New Fatigue Laboratory Opened at Abington

SOME measure of the growth of the British Welding Research Association since its incorporation in 1946 as a grant-aided research association under D.S.I.R., can be obtained from the fact that, whereas in 1945/46 the Association had 43 members and a total income of £33,900, the most recent figures are 254 members and £88,600 income. The activities of the Association are carried on at 29, Park Crescent, N.W.1, which was converted for use as Head Office and Metallurgical Laboratories, and at Abington Hall, some 8 miles south-east of Cambridge, which was purchased in 1946 for development as the Engineering Research Station.

The north end of the new laboratory.

Large Scale Fatigue Testing

The dangers of fatigue failure have been known for years, especially in the field of mechanical engineering where rotating and reciprocating parts must be designed to have lives of many millions of load cycles. In recent years, however, the designers of larger structures have become interested in the subject, notably in the aircraft and shipbuilding industries. The necessity for testing facilities for quite large structural assemblies has become apparent, since the notch effects, both geometrical and metallurgical, introduced by welding and all other methods of fabrication, place further limitations on the strength of materials usually tested as machined laboratory specimens.

Large scale fatigue testing equipment is already used by the scientists of the armed services, but it is to provide these facilities for industry in general that the British Welding Research Association has recently expanded its Abington premises by the building of a new Fatigue Testing Laboratory, which was opened by Lord Woolton on 23rd June, 1952.

The Association has extensive research in progress on fatigue strength, which when concluded will have a vital influence on the strength and economy of welded structures. Until recently, these investigations had to be carried out by the most economical means available, which proved to be the application of the resonance method. Whilst useful results have been obtained, the limitations of the method have become increasingly clear. One of the more important of these is the fact that only equal tension and compression stresses can be applied, and that the stress produced is a function of the design of the part under test. It is, therefore, very difficult to compare different structures, particularly for example, in attempting to compare welded with riveted structures. The limitations of the resonance testing method are overcome by the use of the Losenhausen fatigue testing machine recently acquired by the Association.

Fatigue testing is attractive even for component designs not intended for severe pulsating loads in service, since it provides a very sensitive comparison for alternative joint details. Static loads in many of these cases would be accompanied by full ductility, and ultimate failure in the material itself rather than at the notches.

It is increasingly obvious that the background of structural failure in many cases, including fatigue, is the propagation of a crack in an otherwise ductile material. In parallel with a full programme of structural testing, the Association intends to study the mechanics of crack propagation, in an attempt to understand how this type of failure can be averted.

The New Laboratory

With its office accommodation, the new laboratory has a floor area of 5,000 sq. ft. and is, apart from its contents, a building of considerable technical interest. The Association has, for many years, worked in close collaboration with Prof. J. F. Baker, of Cambridge University, on his plastic design theory as applied to welded structures. It is fitting, therefore, that the first new building based on his theories should be erected at the Association's own Research Station. It can be seen, even at a casual glance that a most economical building has been erected, containing remarkably little steel. This result, as well as the pleasing æsthetics of the building, owes much to the ingenuity of the architect, Mr. George Coles, and other consultants.

The laboratory houses not only the Losenhausen machine but also four resonance testing rigs and a Denison 50-ton Universal testing machine. Other equipment is being added, the chief of which is a double-ended slow speed 100-ton fatigue testing machine of the Illinois type. Further additions will be made when circumstances permit.

Adjusting a specimen in the Losenhausen fatigue machine.

Losenhausen Fatigue Machine

The Losenhausen hydraulic machine is one of the largest fatigue testing machines in the country, and is capable of applying dynamic loads under pulsating tension, pulsating compression, or alternating conditions. It has a maximum dynamic range of 100 tons load, which can be applied within any two limits which do not exceed 100 tons tension or 100 tons compression. It is also suitable for carrying out static tensile, compression, buckling and bending tests up to a maximum load of 200 tons.

Although there are other machines of this type in the country, none has a greater loading capacity, and none is able to take so large a specimen. Axially loaded test pieces up to 6 ft. clear length can be accommodated, and bending tests can be carried out on specimens between 1½ ft. and 6½ ft. in length and up to 18 in. in width. The maximum extension which can be applied to specimens is 0·2 in. and 6 in. for the dynamic and static conditions, respectively.

An extensive series of tests has been started with the object of comparing the resistance to fatigue of various types of standard welded joints. The work may later be extended to attempt a numerical assessment of the influence on fatigue life of various types of weld defects.

100-ton Simple Lever Fatigue Testing

At present under construction in the new laboratory is a copy of the type of machine designed and used by Prof. W. M. Wilson, of Illinois University. The designs were made available to the Association by Prof. Wilson, and the component parts have been contributed by 16 firms and government departments, working in collaboration, with the B.W.R.A. co-ordinating production requirements. The machine has two working heads actuated by simple lever beams with a 15 : 1 magnification ratio. Each beam is driven through a double-eccentric gear which can be adjusted to transmit alternating or pulsating loads to the specimens. The maximum load capacity and load range is approximately 100 tons, and the maximum speed is in the region of 180 cycles per minute.

Pulsating Pressure Plant

Although not housed in the new laboratory, in considering the fatigue testing facilities of the Association, reference should be made to the Werner and Pfleiderer pulsating pressure plant located in the Pressure Vessels Research Laboratory. This equipment, which is unique in this country, permits fatigue tests to be made on pipe lines and pressure vessels by subjecting them to pulsating internal pressures. The plant can operate at a speed as high as 100 cycles per minute with small vessels or low pressures, and at a maximum pressure of 6,000 lb./sq. in. The use of such valuable testing facilities should provide a great service to the welded vessel and pipe industry, since the application of such severe test stresses will permit the rapid discovery of faulty designs or imperfect welding techniques.

Conclusion

The new laboratory and its contents have all been installed and paid for by the Association within the last two years. This has been possible only because of the forward-looking policy, the goodwill and co-operation of members of the Association, and of many other friends. The Association likes to think that these signs of goodwill are an expression of appreciation of the value to industry of the work that is being done.

New No. 3 Blast Furnace Blown-in at Margam Works

THE new No. 3 blast furnace at the Margam works of the Steel Company of Wales has been " blown-in " and has produced iron for the first time. The furnace, which has a 25 ft. 9 in. hearth diameter, is the second such furnace to be erected as part of the development project which has been carried out at the works since 1947.

The furnace stands on a site formerly occupied by a 16 ft. furnace which was completely dismantled before erection of the new furnace could begin. Work on the dismantling of the old furnace began on the 8th November, 1950, the day after the new No. 2 furnace came into operation. By February, 1951, the old furnace had been completely dismantled, after which the foundation block had to be removed and the new foundation block constructed. Erection of the steel work for the new furnace began in July and bricking in September, 1951. Altogether 2,000 tons of steel work and more than 250,000 refractory bricks have been used in the erection of this furnace.

Air for the operation of the furnace is supplied from the new No. 3 turbo-blower which was recently given a trial run-up by H.R.H. The Duke of Edinburgh when he visited the Margam power house on May 8th.

The new furnace is capable of producing 1,000 tons of iron per day, given suitable iron ore, and its completion marks another important step in the reconstruction programme of the Margam Works.

Economy in Steel Alloying Elements

Guide to Alloy Steel Direction

Alloy Steel Direction No. 1, which recently came into force, is designed to achieve economies in the use of nickel and molybdenum by defining the steels of the En. Series which may be used in relation to the properties required in the ruling section concerned. This note is intended to serve as an introduction to the Direction.

WITH the issue of Alloy Steel Direction No. 1 (1952), which came into force on June 2nd, 1952, the opportunity has been seized of ensuring the utmost economy in the use of nickel and molybdenum in those steels where their primary effect is to increase hardenability, namely in steels for hardening and tempering in sizes up to 6 in. ruling section and in carburising steels.

A glance at almost any page of B.S.971 : 1950 will provide examples of two or more steels, differing widely in composition, yet heat treated to give similar specified properties in similar section sizes. The use of the most economical steel available, in terms of its nickel and molybdenum contents, is now to be made obligatory. The terms of the Direction specify the maximum nickel and molybdenum contents for the steels concerned ; the maxima vary with tensile strength and with ruling section. For practical purposes these requirements have been translated into tables showing the En. steels which fall within the composition limits and to the use of which the consumer is therefore confined. Table I shows the permitted En. steels for hardening and tempering, and Table II those for case hardening.

Steels for Hardening and Tempering

With certain minor variations, to which attention is drawn in the notes to Table I, the steels for hardening and tempering comprise a selection from the full range given in B.S.970 : 1947 and the information on them, included in B.S.971 : 1950, is apposite. A heavy line has been drawn through Table I, and it will be found that above and to the left of this line, the only steels available are En. 15, 18, 100, 110 and 111. These steels may be freely used where suitable above 45 tons/sq. in., whatever the ruling section, and the Table merely indicates their probable limitations. From the point of view of alloy conservation, the use of En. 18 or 100 is preferable to the use of En. 110 or 111, where they are interchangeable.

The remainder of Table I includes En. 24, 25, 26, 29 and 30. These steels are higher than the previous group in alloy content, and their use for (ruling section)—(tensile strength) combinations lower than those tabulated is not permitted. These steels, in other words, must not be downgraded. (The exceptional case is where permission to do so has been obtained from the Director of Alloy Steel Control).

Certain steels, notably En. 21, 22, 23, 27, 28 and 160, are thus completely excluded, on account of their too liberal use of nickel and/or molybdenum, whilst those remaining in the permitted list are specifically reserved for use where the required properties are obtainable in no more economical way.

TABLE I—STEELS FOR HARDENING AND TEMPERING—EN SERIES

<table>
<tr><th>Properties as Treated Tons/Sq.In.
Ruling Section at Time of Heat Treatment</th><th>R
45/55</th><th>S
50/60</th><th>T
55/65</th><th>U
60/70</th><th>V
65/75</th><th>W
70/80</th><th>X
75/85</th><th>Y
80/90</th><th>Z
100 Min.</th></tr>
<tr><td>¾ in.</td><td rowspan="3">15
or
18</td><td>15
or
18</td><td rowspan="2">18
or
100
or
111</td><td rowspan="2">100
or
111</td><td rowspan="2">100
or
110</td><td rowspan="2">110
or
24</td><td rowspan="2">24</td><td rowspan="2">24</td><td rowspan="2">110(3)
or
111(3)
or
24
or
30(4 & 5)</td></tr>
<tr><td>1⅛ in.</td><td rowspan="2">18</td></tr>
<tr><td>2½ in.</td><td>100
or
111</td><td>100(1)
or
110</td><td>24</td><td>24(2)</td><td>25(5)
or
26(5)</td><td>25(5)
or
26(5)</td><td>25(5)
or
26(5)
or
30(4 & 5)</td></tr>
<tr><td>4 in.</td><td>18
or
100</td><td rowspan="2">100(1)
or
111</td><td>110</td><td>24</td><td>25(5)
or
26(5)</td><td>25(5)
or
26(5)</td><td rowspan="2">26(5)</td><td rowspan="2">26(5)</td><td>26(5)</td></tr>
<tr><td>6 in.</td><td>100
or
111</td><td>24</td><td>25(5)
or
29(5)</td><td>26(5)</td><td>26(5)</td><td>30(5)</td></tr>
</table>

The figures in parentheses refer to the following notes:

(1) B.S.970 quotes S properties on En.100 only up to 4 in. and U properties only up to 1⅛ in.
(2) B.S.970 quotes S properties on En.24 only up to 1⅛ in.
(3) B.S.970 does not quote 100 tons/sq.in. properties on En.110 or En.111. To attain 100 tons/sq. in. a higher carbon content (0·35–0·45%) is necessary for En. 111.
(4) En. 30 may be used up to 2½ in. for air hardening and tempering only.
(5) The molybdenum content of En. 25, En. 26 and En. 29 must not exceed 0·60% and on En. 308 must not exceed 0·30% without Ministry of Supply assent.

TABLE II—CARBURISING STEELS—EN SERIES

Properties when Heat-treated as 1⅛ in. Bars—Tons/sq. in.	R 45/55	T 55/65	V 65/75	X 75/85	85 Min. Heat-treated as Test-piece Size
	351 or 361	352 or 362	353 or 363	354	355 or 320

It is recommended that all the above steels be used in their appropriate ranges as shown or in higher ranges.

Carburising Steels

Table II is much simpler. With the exception of En. 320, it is confined solely to the new carburising steels, En. 351 to 355 and En. 361 to 363. These specifications were issued as B.S.970 : Addendum No. 1 : November 1951, and were discussed at that time in these pages*. In the months which have elapsed since the publication of the Addendum, alloy steel makers have already commenced to produce satisfactory case-hardening steels to these specifications, and it is now felt that their use can safely be made obligatory.

The attention of consumers must be drawn to the fact that this Direction is limited in scope, and exemption from its requirements is provided for under certain well-defined conditions. First and foremost, the Direction applies only to alloy steel containing more than the specified maximum nickel and molybdenum contents as tabulated, supplied by steelmakers in the form of, or for conversion to, machining bars or forgings (including drop forgings) up to 6 in. ruling section. Machining bars or forgings with a greater ruling section, and similar alloy steels for any other purpose, are not included in the order.

Secondly it is recognised that the specification of alloy steels by means of tensile strength and ruling section alone, does not cover all eventualities, and examples will inevitably occur where a prohibited alloy steel is properly required. To meet such contingencies, a mechanism is set up under the terms of the Direction whereby application may be made for an Alloy Steel Assent, empowering its holder to acquire and use steel for purposes other than those permitted. The procedure to be followed is explained in a pamphlet issued by the Ministry of Supply, entitled "Notes for Consumers of Alloy Steel."

Thirdly, alloy steels, in whatever form used, are still permitted for the following specified purposes :—

(*a*) Corrosion-, heat-, or creep-resisting applications ;
(*b*) Nitriding ;
(*c*) Manufacture of tools, dies, springs, magnets or ball bearings ;
(*d*) For parts subject to A.I.D. inspection, incorporating steels to "S" and "DTD" specifications.

Finally, there is no restriction on the use of alloy steels as billets, machining bars or forgings for export. In this connection the exact meaning of the words "for export" is carefully defined by the Direction.

A direction of this kind is necessarily somewhat complicated, since it must clearly provide for all eventualities. The onus is upon the steel consumer to prove his case if he wishes to step outside the general terms of the Direction. When all the various provisions and exemptions are excluded from attention, there remains a tremendous field in which the Direction will be effective in securing economy of nickel and molybdenum by ensuring that the lowest alloy steel of suitable properties is used.

The very considerable reduction in the number and variety of alloy steels which the steelmaker and stockist are called upon to have available will simplify their task, and contribute towards an easing of the general supply position.

Much of the credit for the fact that this Direction has been produced so rapidly, and is so comprehensive, must go to the unwearied efforts of the Alloy Steel (Rearmament) Technical Committee. It is indeed to be hoped that their work will take its place as a permanent contribution to economy, and that the measures now forced upon us by alloy shortages will not lightly be discarded when those shortages have been overcome.

* *Metallurgia*, December 1951, **44**, 311.

B.C.I.R.A Open Day

FOLLOWING the opening in 1950 of the new machine and instrument shop, mechanical testing laboratory and a staff dining room, the Council of the British Cast Iron Research Association decided on further extensions, to provide adequate accommodation for the existing staff and also to cater for extended work. At a recent "Open Day" we had an opportunity of seeing the progress which has been made. Although the foundations

of a new experimental melting shop are only just being laid and several items remain to be undertaken, the new chemical laboratory is in an advanced state of completion, but is not yet equipped. The spectrographic laboratory houses the recently acquired Quantometer, seen in our illustration, but the remaining apparatus is still to be transferred from the old laboratory. The sands laboratory has moved into its new quarters and the operational research team and development department have been given additional accommodation. This has allowed the "foundry atmospheres" team to take over part of the building opened in 1950, and the heavy stores for pig iron scrap, sands and refractories, envisaged in 1950, have been completed.

The general trend of these changes is to remove the laboratory and experimental work from the original Bordesley Hall building, and for this purpose a further laboratory building will be required to house the metallurgical and chemical research.

The Patent Act 1949 in Action

By S. T. Madeley

With a view to encouraging the flow of inventions in this country, a new Patent Act was introduced in 1949. In this article, the author summarises the extent to which advantage has been taken of certain of its provisions.

THE 1949 Patent Act was the product of a very intense and thorough study of conditions in the patent world as they presented themselves to a Committee appointed after World War II. It was appointed for the purpose of investigating by what means conditions could best be developed to encourage the flow of inventions in this country, for it was by invention that these islands raised themselves from a small poor island group in the North Atlantic to the pinnacle they occupied in the industrial world before World War I. There is little doubt that their future rests largely on an adequate development of inventive genius in the future, since they have lost the advantage which Nature gave them in placing them in a storehouse of readily accessible coal and iron which enabled them to develop their inventions whilst their competitors were not so happily placed.

Early Metal Patents

An early patent dealing with metals was that granted in 1637 A.D. to one Evans: it was numbered 110. The Evans patent was for 'Drawing and raising off waters from overflowing Grounds, Myne Pitts and Coalepitts by the use of Engines by him invented and also to use and practise within the said Realmes and Dominions the refining and working of all Minerals and Mettals, making and burning of Bricks, Tyles, Lymestone, Chalke, and other Terrestreall and Lapideous Materialls after his new invented order. To use and put in practise within England, Ireland, and Wales but not within 20 miles of London!' Patent No. 117 was granted to Horsey and others in 1638 and Patent No. 170 to Slamming in 1673, both dealing with metals. It will be seen, therefore, that there was no rush to patent these matters some three hundred years ago.

One hesitates to think how much Mr. Evans might have had to pay in fees for division had his application been filed to-day! Fortunately for him he was not called upon to describe his invention, nor was there a board of experts sitting to dissect it before allowing him a patent!

About a hundred years later Axel Cronstedt discovered nickel, which now finds so many uses. Since then a long step forward has been made, for in the year 1950 the number of patents accepted by the British Patent Office, under the heading, 'Metals-Extracting, Refining and Alloys' was 136. There was, in that year, considerable patent activity in the realm of metal pit props, and in 1951 of powder metallurgy.

For progress under the new Act we cannot do better in some respects than refer to the Sixty-Ninth Report of the Comptroller-General of Patents, Designs and Trade Marks, a functionary who did not exist in the days of Mr. Evans.

Although the Patent Office is still suffering from the results of the bombing which it received during the War, it employs a staff of over 900, and has a library containing nearly 345,000 volumes which was used by over 75,000 readers during the year 1951.

Under the 1949 Act, Sections 7 and 8 deal with anticipation by prior publication and by prior claim respectively, as under the earlier Acts, and procedure runs on the same lines as before.

Infringement of Prior Claim

Under Section 9, if the Comptroller is of the opinion, in any particular case, that the invention in question cannot be performed without risk of infringement of a claim of another patent, then the Comptroller may direct that a reference to the earlier patent under consideration may be inserted in the later specification. This reference may be avoided by satisfactory amendment, or removed, if already inserted, if the earlier patent is revoked or ceases to be in force, or if the relevant claim is deleted, or—and this is an important point—if the Comptroller or the Court is satisfied that the claim in question is invalid or would not be infringed by any working of the patent applied for. Under this section 21 hearings were appointed.

Where no decision can be reached in a case by direct negotiation between the applicant or his agent and the examiner in charge of the case, the practice is to take the matter to a hearing before a superior officer of the Patent Office. There were 297 such hearings appointed in the year in question. In 43 cases the hearings became unnecessary either because the case was abandoned or the specification was amended so as to avoid the hearing.

Oppositions to grant come under Section 14 under the new Act. The main new features of this section are that prior use and clear lack of inventive step can be used as grounds of opposition. No fewer than 179 oppositions were entered.

Under Section 16(3) an inventor can apply to be mentioned as such in a patent application, and 58 requests under this sub-section were granted.

Section 26 allows patents of addition to be granted in place of independent patents. Only six such applications were made in the year under consideration and two were granted.

Restoration of Lapsed Patents

Lapsed patents and patent applications can be restored under certain circumstances under Section 27. The main grounds of application are that the failure to pay the relevant renewal fee or to prosecute the application, as the case may be, was unintentional and no undue delay has occurred in making the application to restore. Sixty-five such applications were made in 1951 in cases involving failure to pay renewal fees.

If a patent has not been sealed within the prescribed period owing to lack of request, an application can be made to restore under Section 28. Two such requests were made in 1951.

Ninety-five applications for amendment after acceptance were made under Section 29 of the Act, and three notices of opposition were given. Such amendments are made by leave of the Comptroller under this Section. No applications were made under Section 30 to amend by leave of the Court.

Under Section 33 of the 1949 Act, power is given to the Comptroller to revoke a patent. Thirty such applications were made. As might be expected, offers to surrender a patent are rare. This can be done under Section 34 of the Act, but only eight such offers were made.

Section 35 enables patentees to have their patents endorsed "Licence of Right" and thereby save half the renewal fees. There were 449 requests of this nature in 1951, and 10,020 patents were kept in force to the end of the fifth year.

Although there are a number of grounds on which a compulsory licence can be applied for under Section 37—insufficient working; demand in the United Kingdom not being met on reasonable terms; over-importation; unreasonable terms for grant of licence; unreasonable conditions demanded for grant of licence or for purchase, hire, or use of the patented article or process; use or sale of material not protected by the patent; development of commercial and industrial activities in the United Kingdom unduly prejudiced—only two applications were made for such licences.

The 1949 Act empowers the Comptroller to determine disputes relative to inventions made by employees, the power being given by Section 56 on application by either of the parties concerned. One application of this kind was made in 1951.

Under Sections 24 and 25, applications may be made to the Court or the Comptroller, by petition or originating summons, for extension of term of a patent on the ground of war loss by the patentee or exclusive licensee, and 693 applications were made to the Comptroller. Under the war-loss conditions, the loss of time is the ruling factor, not the merit of the invention, but whether the application be made on the ground of merit under Section 23, or of war loss, the total extension is limited to ten years.

Economy in Nickel-Iron Magnetic Alloys

ONE of the most extensively used nickel-iron magnetic alloys is the 76-80% nickel-iron known in this country as Permalloy C or Mumetal. Economy in the use of this metal is essential for several reasons. First and foremost the time during which manpower and equipment is occupied in the rolling of thin strip is surprisingly large. Cutting down the amount used in any one piece of equipment will, therefore, enable just so much more equipment to be made. Secondly, the actual saving in metal is not negligible and shortage of virgin metal is itself a limiting factor in production, and thirdly, less metal means lighter equipment.

Sometimes nickel-iron alloy can be saved by using an alternative metal like silicon iron, and when possible without undue sacrifice of weight and performance this should be done. When nickel-iron must be used, it is essential that designs take full advantage of the properties of the material. These materials are used at low alternating flux densities in transformers and inductors, and at high flux densities in magnetic amplifiers. This note is concerned only with the low-flux-density application; data on high flux densities will follow later.

The published data show that Permalloy C and Mumetal may attain initial permeabilities of 25,000 and 30,000 in closed magnetic circuits, but the general manufactured output of thin strip has been below this level and it has been necessary to design coils and transformers on the basis of about 5,000 metal permeability.

Much progress has been made during the past two or three years and the Telegraph Construction and Maintenance Co. Ltd. and Standard Telephones and Cables, Ltd., will now guarantee the following minimum permeabilities for *spiral strip cores* in Mumetal and Permalloy C. The permeability figures quoted in the table are the guaranteed minimum *core* permeabilities (in which allowance has been made for stacking factor) measured at 50 c.p.s. and $H = 0 \cdot 002$ oersted R.M.S. and refer to sizes similar to those quoted only.

Thickness of strip: inch	Typical core sizes: inch	Minimum core permeability
0·004	2·25 × 1·5 × 0·5 2·25 × 1·5 × 0·375	10,000
0·002	2·25 × 1·5 × 0·5 1·5 × 1·0 × 0·25	7,500
0·001	1·5 × 1·0 × 0·25	5,000

Standard dimensions of cores for Service use are listed in R.C.L. 193, published by the Radio Components Standardisation Committee, Castlewood House, New Oxford Street, London, W.C.1.

For other than spiral strip cores, the manufacturers should be consulted as to guaranteed minimum permeabilities.

Using the above data it should be possible to reduce the amount of magnetic material in each core without in any way lowering performance standards. Smaller cores can replace the present ones, and there should be a saving of scarce material. What is even more important is that the rolling-mill time occupied for each item of completed equipment will be much less than at present.

Johnson Matthey's South African Venture

JOHNSON, MATTHEY & CO., LTD., propose to form a subsidiary company in South Africa under the title of Johnson, Matthey & Co. (South Africa), Ltd., with offices in Johannesburg. The initial objectives will be to meet from local production the industrial needs of South Africa for noble metals, and to manufacture the requirements of the jewellery, dental and allied trades. Mr. J. A. Shaw, hitherto assistant manager of the Shepherd's Bush Works, London, has been appointed manager and will leave for South Africa in September, together with Mr. E. C. Deering, a director of the London company.

Heenan and Froude's Golden Jubilee

Group's Metal Working Plant and Machinery Activities

ALTHOUGH 1952 is the Golden Jubilee year of Heenan & Froude, Ltd., as an incorporated company, it was as far back as 1881 that Richard Hurrell Froude was taken into partnership by Hammersley Heenan who had, in the previous year, purchased the steelworks of Woodhouse & Co. at Newton Heath, Manchester. Froude, who had been a colleague of Heenan in India, was the eldest son of William Froude, F.R.S., the inventor of the Froude hydraulic dynamometer which was brought to the firm by his son.

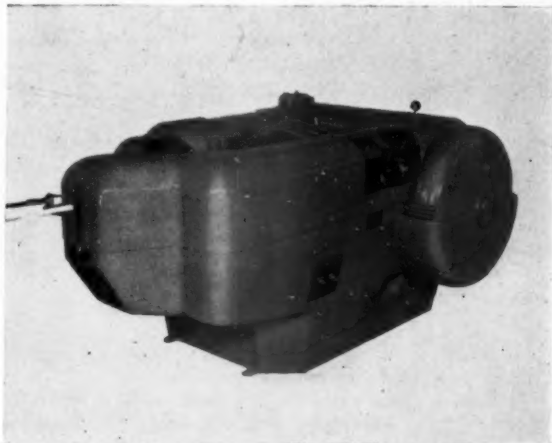
Expansion of the business led to further premises being acquired in Birmingham, but in 1903, these proving too small, a move was made to Worcester. The Manchester works was retained as a constructional steel works, and it was not until 1935 that these premises were relinquished.

Widening Interest

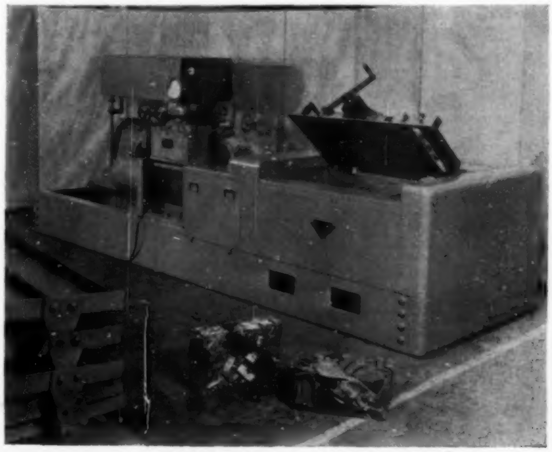
At first, the firm specialised in constructional engineering, one of its outstanding contracts being for the erection of Blackpool Tower, but the Froude dynamometer soon became its mainstay. Water coolers were added in 1906 to be followed by the Heenan air filter for power stations and the Heenan closed circuit air cooler.

1934 saw the beginnings of a new range of specialities, the Heenan automatic machines for the wire, strip and chain industries, while in 1938 world rights (excluding North America) were secured for the Heenan-Dynamatic dynamometer and the Heenan-Dynamatic coupling, which have since undergone considerable development. For more than fifty years an important part of the Company's business has been the design and supply of municipal refuse disposal plants.

In 1936, a policy of expansion was initiated with the purchase of the old-established firm of Court Works, Ltd., specialist iron founders of Madeley, Shropshire. Since that time the Heenan & Froude Group has been enlarged to include also Fielding & Platt, Ltd., Associated Locomotive Equipment, Ltd., W. G. Bagnall, Ltd., Industrial Waste Eliminators, Ltd., Morton Machine Co. Ltd., and New Destructor Co. Ltd.



Heenan automatic strip forming machine.



Heenan hydraulic double ram scrap metal baling press.

The Works To-day

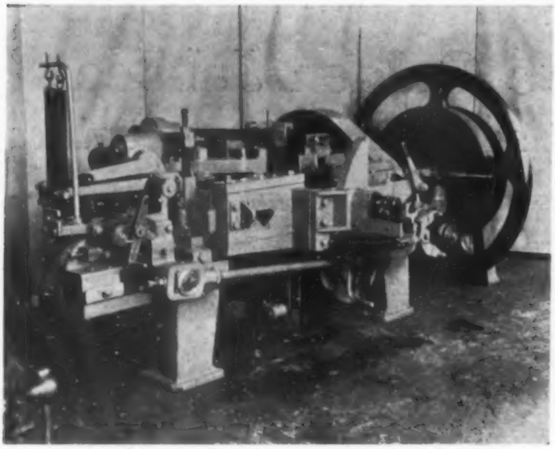
The Worcester premises have been enlarged from time to time since they were taken over until, to-day, an area of eight acres is covered and approximately 1,100 persons are employed. The office building, erected in 1937, is of the most modern design, the entire top floor consisting of a drawing office 250 ft. long. The workshops themselves, besides light and heavy machine and assembly shops, include a foundry, with associated pattern shops, in which the high-quality erosion-resistant castings necessary in hydraulic dynamometer equipment are made in plain or alloyed cast iron and semi-steel. They include also a fully equipped plating shop capable of fabricating material up to 2 in. thick.

Metal Working Plant

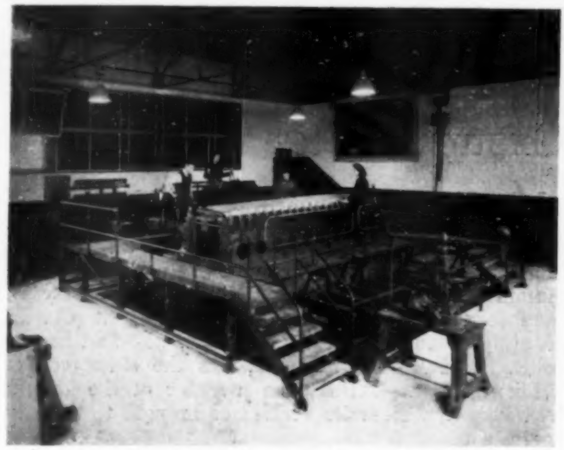
Of the varied products of the Company, those offering greatest interest to the metal producing and consuming industries are the automatic wire and strip manipulating machines, the baling presses and the oil coolers suitable for cooling the quenching oil in heat treatment shops.

Included in the first group are cold chain forming machines for use with material from $\frac{5}{64}$ in. to 1 in. diameter; chain welding machines; complete equipment for chain making by a hot process, where wire diameters between $\frac{7}{8}$ in. and $1\frac{3}{8}$ in. are involved; high-speed nail presses; and a wide range of machines for forming wire and strip into such things as paper clips, fence staples, lock-washers, mattress chain, jack chain, etc.

The range of baling presses suitable for scrap metal includes a number of mechanical and hydraulic models capable of producing bales up to 112 lb. weight. One of



Heenan automatic chain forming machine.



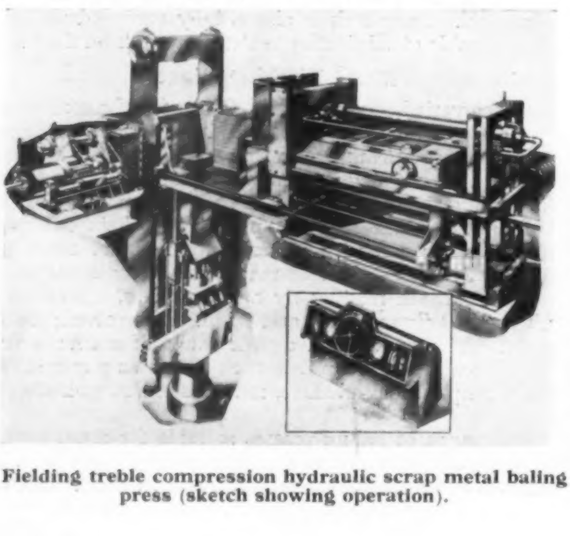
Fielding 560-ton stretch forming machine.

the mechanical models has been developed expressly for light alloy scrap producing a 25–50 lb. bale suitable for crucible charging.

Fielding and Platt, Ltd.

Like Heenan & Froude, Fielding & Platt, Ltd., was founded in the latter half of the 19th century, when Samuel Fielding and James Platt, both of Gloucester, started a small general engineering business at Atlas Works, in St. Luke's Street, Gloucester, in 1866. In 1871 they became associated with Ralph Tweddell and Fielding hydraulic riveters embodying the Tweddell system gained the highest awards at international exhibitions between 1875 and 1885. Thus began the Company's interest in hydraulic engineering which has since been extended to the manufacture of a number of types of presses, pumps and accumulators. In 1908, gas engines were added to the firm's products, followed by a range of oil engines whose manufacture was taken over in 1939 by Messrs. Petters, Ltd. The Company was acquired by Heenan and Froude in 1939.

In its 86 years' history, the Company has achieved a world-wide reputation for the design and manufacture of hydraulic equipment. To-day, it is concentrating on the provision of service, and the development, design and manufacture of the most modern hydraulic equipment to meet the present and the future needs of industry.



Fielding treble compression hydraulic scrap metal baling press (sketch showing operation).

Wartime Activities

During the first World War the Company's activities were devoted almost entirely to Government requirements for the manufacture of presses for a wide range of shells up to 16 in., equipment for shipyards, and other essential purposes. After the war, the range and size of the Company's products were considerably expanded for equipping railway workshops, shipyards, etc., and included many types of presses for the forging and manipulation of metal. Presses for plywood and concrete were also made in considerable quantities.

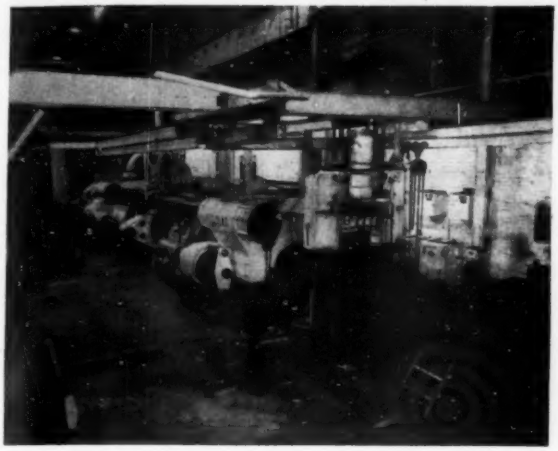
During the second World War, the Company produced numerous hydraulic presses to the requirements of Government Departments for the manufacture of components for aircraft, munitions, etc., notably extrusion presses and other equipment for the production of light alloys. Important developments included high-speed variable delivery and other types of pumps in a wide range of sizes and pressures for the direct operation of hydraulic units. The gas-loaded types of accumulator were also produced in an improved form.

The Works

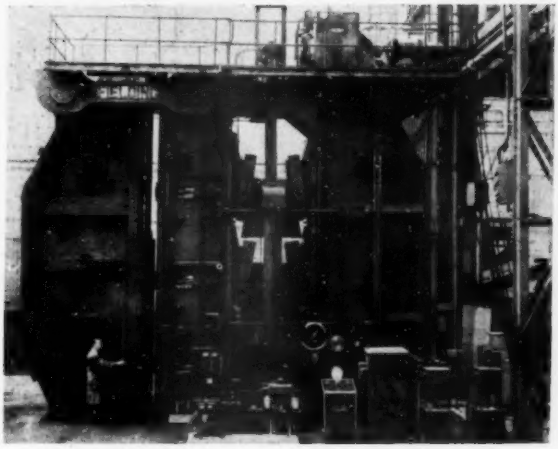
The original small workshops of the early days have been extended to cover three-and-a-half acres, where 650 workpeople are now employed. These works have been completely re-equipped with modern machine tools, of types and capacities for the production of the most advanced types of plant.

The heavy machine shop is equipped for the machining of the heavy components, in cast iron, mild steel or alloy steel, used in the production of Fielding presses, pumps and other equipment, whilst similar operations are carried out in the light machine shop on smaller components associated with pumps, valves and control equipment.

Ferrous castings are purchased from outside sources, but there is a non-ferrous foundry for the production of



Fielding 8,000-ton horizontal hydraulic extrusion press.



Fielding 360-ton vertical plate bender.

small castings in gun metal, phosphor-bronze and, in some cases, aluminium alloys.

Special facilities are provided for the complete erection and testing of hydraulic presses. Owing to the height of some of the equipment, it is not possible to erect at floor level, and several large erection pits are used for this purpose.

There are, in addition, the usual auxiliary departments such as tool room, welding and pipe shop, stores, metal fabrication department, etc.

Products

Fielding & Platt produce a number of types of equipment in the metallurgical field, amongst which is included a range of presses for working and forming metal. The operations covered include extrusion, piercing, cable sheathing, plate bending, upsetting, forging, flanging, joggling, hobbing, stretching, de-twisting, forming, straightening and drawing.

Whilst not strictly metal working presses, mention should also be made of the scrap metal baling presses and briquetting presses, the latter being designed for compacting swarf before remelting. Presses are also made for plywood, concrete tiles, paving slabs, etc., and other Fielding products include fixed and portable riveters, shipyard equipment, boiler shop plant, railway workshop plant, hydraulic accumulators and pumps, variable delivery-oil pumps, intensifiers, etc.

Britain's Largest Steel Ingot

ALREADY pre-eminent as engineering steelmakers and as manufacturers of high-pressure one-piece forgings for power stations, oil plants, chemical and allied steel processes, English Steel Corporation, Ltd. of Sheffield, have recently cast at their River Don Works the largest steel ingot ever made in Great Britain.

This ingot is 26 ft. long and 9 ft. across the largest octagonal section, and required 270 tons of special steel from four acid open hearth furnaces. Apart from the high technical skill required in the casting of such a large ingot, the lifting and transport also set many problems. Two cranes coupled by a specially constructed lifting beam were used, and to ensure co-ordination of lifting and perfect teamwork in other phases of the operations, several rehearsals were necessary, a smaller ingot of 210 tons being used for this purpose.

When stripped from the mould the ingot was loaded on to a 300 ton, 24 wheeled railway bogie, specially built for E.S.C. for the internal transport of large ingots, forgings and castings, and was taken for further processing. The ingot will be forged under a 7,000 ton electro-hydraulic press at River Don Works into a one-piece hollow forged boiler drum, the largest of its type ever made in this country and possibly in the world.

Ordered by Clarke Chapman & Co., Ltd., Gateshead, for a new power station for the British Electricity Authority, this drum, when finished, will be 42 ft. long, 6 ft. 2½ in. outside and 5 ft. 6 in. inside diameter.

Porous Stainless Steel

A New Filter Material

JUST over two years ago, we were privileged to see demonstrated, in the laboratory, the porosity of a piece of stainless steel sheet which had been made by powder metallurgy methods. Since that time, a good deal of development work has been carried out on the production of this material, and to-day not only can stainless steel sheet of controlled porosity be made regularly, but various types of filter fabricated from it are available commercially. Never before has stainless steel powder been used for the manufacture of a filtering medium in this country, and this new application is now introduced by The B.S.A. Group of Companies.

Powder materials for filtration in both the scientific and industrial fields have been previously available as powdered or porous refractories, or as non-ferrous metals. Unfired porcelain and ceramics suffer from low shock strength, while non-ferrous filter materials, such as the porous bronzes, are subject to a relatively low operating temperature. Furthermore, many non-ferrous materials have insufficient corrosion resistance and are chemically attacked by many industrial reagents.

The B.S.A. Group Research Centre has evolved a new method of producing low carbon stainless steel powder of the 18 : 8 variety. This powder is highly resistant to most acids (the main exception being hydrochloric), alkalis, organic compounds and salts, and is of the sharp angular form necessary to ensure the requisite mechanical strength in the final compact. The new method of production of this 18 : 8 stainless steel powder ensures that individual grains are free from internal stress, and have a particle size distribution within closely controlled limits.

Manufacture

Porous aggregates can be produced by spreading stainless steel powder on to a ceramic base and sintering the layer so formed in a reducing atmosphere. Sintered plates produced in this way have been found to possess a non-uniform permeability. The B.S.A. Group has developed a means of producing stainless steel compacts of high industrial uniformity and reproducibility.

Commencing with the production of a special type stainless steel bar stock which is subsequently disintegrated to powder, all manufacturing stages have to be scientifically controlled. The powder is chemically analysed and physically graded before compacting, and the resulting graded powder is thoroughly mixed with a porosity forming agent which volatilises during the initial sintering operation. Pressing in dies results in a uniform compact of controlled porosity. The "green" pressings, usually in sheet form, are initially sintered, and finally re-sintered, at a high temperature in a reducing atmosphere of dry hydrogen. This procedure promotes the diffusion welding of mutually placed angular particles, thus ensuring porous-metal compacts of high strength and ductility.

This method of manufacture, due to press and furnace capacity, imposes at present a limit on the size of unit compact which can be produced. The largest available industrial sheet has a surface area of approximately 54 sq. in. As the limitations on thickness are not so severe, a wide range of thicknesses is available.

Considerable research effort has been expended on determining the most efficient method of joining the unit compacts, and a new technique has been evolved so that the specific requirements of users can be met by fabricating the complicated final forms of different filters from simple porous metal unit pressings. Finished filters are subjected, before release, to a heat treatment process which ensures mechanical stability without reduction of chemical corrosion-resisting properties.

The cleaning of clogged filters is essential in industrial plants and various treatments can be followed. A reverse flow or back-washing will generally clean all but the most adherent contaminants. In cases where the removal of clogging particles is desirable by chemical treatment, either boiling in 20% sodium hydroxide solution, or in 15% nitric acid solution can be adopted.

Available Grades

A range of porosity may be obtained by the controlled variation of one or more of the following factors : (*a*) the compacting load ; (*b*) the size and amount of the porosity-forming addition ; and (*c*) the particle size and distribution in the original powder. In this way a range of standard grades has been made available with air flow rates varying from 3 cu. ft./min. to 61·2 cu. ft./min., measured at standard temperature and pressure when a differential pressure of 0·1 lb./sq. in. exists across the porous plate of $\frac{1}{8}$ in. thickness and surface area 1 sq. ft. It will be appreciated, of course, that with increasing permeability there is a fall in mechanical strength of the compacts.

Applications

It is thought that the main markets for this new product will be in the industrial and scientific fields. The chemical industry will doubtless require fabricated filters for air lines, main purified water lines, and possibly as flow surge suppressors. The filtering of reaction products from a fluidised catalyst is a further important application, since the cost of the catalyst itself often makes its complete removal without loss very desirable. In research investigations, laboratory filters and bubblers are often required which must withstand high operating temperatures and corrosive reagents.

A number of standard engineering filters (including twelve-pointed star units having a total effective surface area of 9 sq. ft.) are available, whilst flow steadiers and porous plugs can be supplied to requirements. On the laboratory side there are such items as filter crucibles, Buchner funnels, beakers, aerators and immersion tubes.

WILD BARFIELD ELECTRIC FURNACE, LTD., in conjunction with their associates, G.W.B. Electric Furnaces, Ltd., have established an office at 131, West Regent Street, Glasgow, C. 2 (Tel. : Douglas 8839), to enable them to increase still further the sales and service facilities of the joint companies. The office will be under the control of their present Scottish representative, Mr. D. McDermott.

Applications of Copper-Clad Aluminium

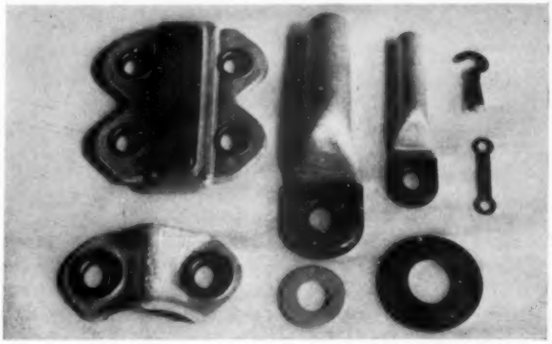
READERS may recall that in the Metallurgical Digest section of our June issue, there appeared a condensed version of an American article with the title "Copper-Clad Aluminium Can Conserve Copper in Many Uses." We have since learned that this material, under the trade name of Cupal, is being handled by North Western Metal Products, Ltd., of Viaduct Works, Cavendish Street, Ashton-under-Lyne, Lancs., who are the sole agents for this country. The digest referred to gave particulars of the physical and mechanical properties of the material with varying proportions of cladding, and reference was made to some of the slight modifications advisable in working and machining.

Cupal has been produced in Germany for more than 15 years, and has proved its usefulness in many industries, both during and since the war. It consists of a covering layer of copper on pure aluminium, the bond between the two being exceptionally good. There are, of course, a number of ways of making compound materials. The surfacing can be applied by spray or by electroplating, both methods being satisfactory in certain cases, and both having the common disadvantage that the covering layer is comparatively thin and often not uniform. Furthermore, there is a tendency for the coating to peel off when worked. For this reason, the so-called clad materials, made by heating the two metals by means of special processes and uniting by hot rolling, are preferable where higher stresses are expected. The excellence of the bond in the case of Cupal is shown by the mechanical and thermal stressing which can be applied to it without evidence of lamination.

Available Forms

The material is available in the form of sheets, circles, strips, busbars, etc., in thicknesses varying from 40 s.w.g. to $\frac{5}{16}$ in. One or both sides may be copper clad, the thickness of the aluminium in the standard grades being 70%, 80% or 90% of the total. For each application, it is necessary to decide what thickness cladding is required, and whether the material should be clad on one or both sides. In general, it can be said that the thicker the copper cladding, the more capable of working and of resisting stress is the material, but it is not necessary to have a thick coating of copper in every case. Care should be taken, however, to see that neither manufacturing nor service conditions are likely to bare the aluminium locally, particularly where corrosive conditions are likely to be encountered, because of the distance apart of the two materials in the electrochemical series. For the same reason, it may be necessary to protect cut edges by lacquering, or other means, if exposure in a corrosive environment is likely.

Decorative ware made in Cupal.



Cupal is used for the eyelets of the clamp and cable lug and for the washers and links.

Applications

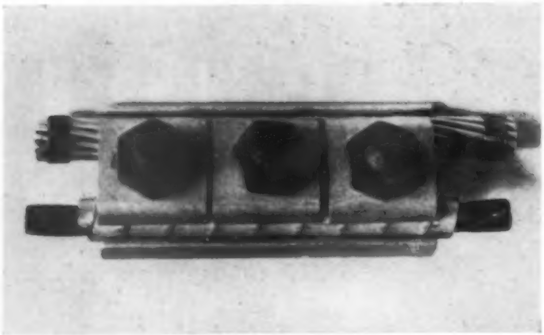
The properties of Cupal are such as to suggest a number of applications and the inherent possibilities of the material may best be illustrated by describing, in relation to its properties, some of the uses to which it has been put in Germany.

The facility of polishing and grinding, and more especially the possibility of electroplating in standard baths, led, among other things, to an extensive use of Cupal sheet for the manufacture of reflectors. Besides its very high reflectivity, the use of Cupal results in a considerable weight saving, which is of importance in transport, particularly in the air.

Compared with other materials used for heat exchangers, e.g., iron, zinc, aluminium, Cupal possesses, usually, a considerably higher thermal conductivity. The resulting suitability for heat-exchange apparatus is increased by the possibility of joining Cupal parts by soft soldering to produce a thermally effective joint.

If the copper surface layers are adapted to the intended use, they give to the core or under layer of aluminium the corrosion-resistant property of the copper, valuable, for example, in case of continual contact with hot or cold water, whereas single-coated Cupal sheets permit the properties of both metal layers to be utilised Such an application is to be found in domestic coal-fired hot water boilers where the copper layer is on the water side and the aluminium layer, with its greater resistance to the flue gases than copper, on the fire side.

The copper surface layers can be soldered as easily as copper, brass, etc., and this applies not only to the possibility of joining Cupal to Cupal but also to other solderable metals. Spot welding of the single clad



Aluminium and copper cables in a light metal clamp. Corrosion risks are overcome by winding the copper cable with Cupal "tape."

material is quite satisfactory with the aluminium sides in contact.

Because of its suitability for stamping and soldering, combined with the excellent finishes which can be applied, the clad material offers possibilities for the production of fancy goods, badges, plaques, metal letters, belt clasps and similar articles, a field which may, perhaps, be of greater significance in times of shortage of the usual materials than it would normally be.

Electrical Uses

There is little doubt, however, that it is in the electrical field that Cupal is likely to prove of most interest. The ease of soldering and its light weight would suggest a possible use as a chassis material in airborne radio equipment, whilst the skin effect with high frequency current may result in its having equal conductivity with copper in H.F. circuits.

In the field of more normal conductors, Cupal is likely to prove of considerable value. There is a trend towards the greater use of aluminium conductors, whose lighter weight results in less robust supports being satisfactory, but there is usually at some stage the necessity of joining the aluminium to a copper member. This introduces a contact problem, as the resistance of such a joint is liable to increase considerably as a result of electrochemical corrosion. By the use of single clad Cupal washers or shims, suitably protected at the cut edges, the only copper to aluminium joint is within the Cupal and away from any corrosive agents. For similar reasons, the material is used for cable lugs, soldering eyes, connecting clips, etc.

B.T.H. Engineering Research Fellowships

THE British Thomson-Houston Company, in pursuance of its progressive policy in technical education and the advancement of young men of ability, has recently instituted an annual award of Engineering Research Fellowships.

The award is open to Honours graduates who are in their last year of apprenticeship with the Company. The holder of a Fellowship will engage in engineering research for a limited period (one to three years) either wholly within the Company or partly within the Company and partly at a University. He will work under the supervision of a senior engineer of the Company and under the guidance of a Research Fellowship Panel set up for the purpose. The Director of Research and Education is Chairman of the Panel which includes other senior executives of B.T.H. and, in addition, Professor E. B. Moullin and Professor Willis Jackson. This year (1952) Fellowships have been awarded to P. H. G. Allen and P. C. McNeill, who will carry out research on heat flow in large transformers and secondary emission coefficients in magnetrons.

"Kunifer" Cupro-Nickel Alloys

THE Metals Division of Imperial Chemical Industries, Ltd., has added Admiralty-quality 70/30 cupro-nickel to its " Kunifer " range of cupro-nickel alloys containing additions of iron and manganese. The I.C.I. trade name " Kunifer " originally referred to alloys having 5% and 10% nickel content, covered by the British Non-Ferrous Metals Research Association patent numbers 577065 and 578283 but, as the Division's well-known " AE Super-nickel " condenser-tube alloy has for many years contained additions of iron and manganese in accordance with Admiralty Specification 3T.102, to bring it into the " Kunifer " range is an obvious measure of standardisation. The three alloys will be distinguished by numerical suffixes indicating the nickel content. " Kunifer " 5, in either tube or sheet form, is an alloy particularly suitable for sea-water trunking systems, and " Kunifer " 10 is an alloy with a variety of special tube applications, whilst " Kunifer " 30 is the I.C.I. cupro-nickel condenser-tube alloy to British Admiralty requirements.

Iron-Ore Plant for Yugoslavia

A CONTRACT for a complete iron-ore handling plant to the value of over £1 million has been confirmed between The General Electric Co., Ltd., of England and Invest Import, Belgrade. The plant, which is to have a capacity of 500/690 tons per hour, includes mechanical and electrical equipment and will be manufactured at the Fraser and Chalmers Engineering Works and the Witton Engineering Works of the G.E.C. Delivery to the Zenica Iron Works, Yugoslavia, is scheduled for two years. This installation will form part of a complete iron-making plant, the consultants for which are Meckenzie Engineering, Ltd., of London.

Secondary Light Alloy Prices

THE Federation of Secondary Light Metal Smelters announces that following the increase in the price of virgin aluminium as from July 1st, and the order made by the Ministry of Supply increasing the maximum prices of aluminium scrap from July 14th, its members find it necessary to increase the maximum selling prices of the undermentioned alloys on and from Monday, July 28th, as follows :—

L.M.1	From £163 per ton to £166 per ton
L.M.2	From £181 ,, ,, ,, £183 ,, ,,
L.M.4	From £169 ,, ,, ,, £172 ,, ,,
L.M.6	From £190 ,, ,, ,, £193 ,, ,,
Deoxidising Sticks 85/90	From £149 per ton to £151 per ton

NEWS AND ANNOUNCEMENTS

The Institute of Metals

Symposium on Properties of Metallic Surfaces

AN all-day Symposium on "Properties of Metallic Surfaces," arranged by The Institute of Metals, will be held in the Lecture Theatre of the Royal Institution, Albemarle Street, London, W.1, on Wednesday, 19th November, 1952, from 9-45 a.m. to 5 p.m.

The papers contributed to the Symposium will be discussed at two sessions, as follows :

SESSION I.—(MORNING)

(a) "Specialised Microscopical Techniques in Metallurgy," by Professor S. TOLANSKY, F.R.S. (Royal Holloway College, University of London).

(b) "Radioisotopes in the Study of Metal Surface Reactions in Solutions," by Dr. M. T. SIMNAD (Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pa., U.S.A.)

(c) "The Crystalline Character of Abraded Surfaces," by Dr. P. GAY and Dr. P. B. HIRSCH (Cavendish Laboratory, Cambridge).

(d) "Diffusion Coatings," by Mr. D. M. DOVEY, Dr. I. JENKINS and Mr. K. C. RANDLE (Research Laboratories, The General Electric Co., Ltd., Wembley).

(e) "The Nature and Properties of the Anodic Film on Aluminium and its Alloys," by Mr. H. W. L. PHILLIPS (Research Laboratories, The British Aluminium Co., Ltd., Gerrards Cross).

(f) "Chemical Behaviour as Influenced by Surface Condition," by Dr. U. R. EVANS, F.R.S. (Cambridge University).

(g) "The Effect of Method of Preparation on the High-Frequency Surface Resistance of Metals," by Dr. R. G. CHAMBERS and Dr. A. B. PIPPARD (Royal Society Mond Laboratory, Cambridge).

SESSION II.—(AFTERNOON)

(a) "The Influence of Machining and Grinding Methods on the Mechanical and Physical Condition of Metal Surfaces," by Mr. P. SPEAR, Mr. I. R. ROBINSON and Mr. K. J. B. WOLFE (The B.S.A. Group Machinability Laboratory, B.S.A. Tools, Ltd., Birmingham).

(b) "The Effect of Lubrication and Nature of Superficial Layer After Prolonged Periods of Running," by Dr. F. T. BARWELL (Lubrication Division, Mechanical Engineering Research Organisation, Department of Scientific and Industrial Research, Glasgow).

(c) "The Effect of Surface Conditions on the Mechanical Properties of Metals, Mainly Single Crystals," by Professor E. N. DA C. ANDRADE, F.R.S.

(d) "The Effect of Surface Condition on the Strength of Brittle Materials," by Professor C. GURNEY [University College, Cardiff (University of Wales)].

(e) "The Influence of Surface Condition on the Fatigue Strength of Steel," by Mr. R. J. LOVE (Motor Industry Research Association, Brentford).

(f) "The Influence of Surface Films on the Friction and Deformation of Surfaces," by Dr. F. P. BOWDEN and Dr. D. TABOR (Cambridge University).

Attendance at the meeting will be free to all who are interested in the subject. Non-members of the Institute who wish to register for the meeting should apply to the Secretary, The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1, to receive a copy of the programme of the meeting and registration form, which will be available in August.

Students' Essay Prize Competition

A STUDENTS' Essay Prize for 1952 has been awarded by the Council of the Institute of Metals to Mr. John C. Wright (student member), laboratory assistant, Development and Research Department, The Mond Nickel Co., Ltd., Birmingham, for an essay on "The Metallographic Investigation of Failed High-Temperature Components." The prize of 20 guineas will be given in the form of 10 guineas in money and 10 guineas in books to be selected by the prize winner. The essay has been recommended for publication, and will be printed in the September issue of the Institute's *Bulletin*.

For the 1953 Competition the Council of the Institute will present two such prizes for the best essays submitted. The competition is open to all student members of the Institute and to all associate members of local sections who are eligible for student membership of the Institute, provided that both are within the normal age limits for such membership, *viz.*, 17 to 25. The choice of subject is left to the competitors, except that subjects related exclusively to extraction and ferrous metallurgy are excluded.

Further particulars can be obtained from The Secretary, The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1, to whom entries must be submitted not later than Thursday, 1st January, 1953.

Leeds Metallurgical Society

Metal Shortage Conference

THE recent metal shortage has introduced many serious problems in industry, particularly with regard to the use of alternative materials. Although the position is changing now with respect to some base metals, certain strategic metals are likely to be scarce for some time. To enable information to be exchanged the Leeds Metallurgical Society proposes to hold a week-end conference on "Problems arising from Metal Scarcities and the use of Alternative Materials."

The conference will be held at a very attractive venue within two miles of Leeds City Centre, commencing Friday evening, September 5th, and finishing Sunday afternoon, September 7th. This project has the support of the Metal Economy Committee, Ministry of Supply and a number of speakers of national standing will be present to initiate and take part in the discussions.

Certain sessions have been reserved for discussion of problems that are experienced by local industries. Some suggestions for these subjects have included : (a) heat treatment of alternative En steels ; (b) alternative protective coatings ; (c) substitution of non-metallic materials ; and (d) scrap recovery. It is particularly requested that those interested indicate any problems which are causing particular concern.

All interested in the use of metals in the engineering and allied industries are cordially invited to attend the conference, and it is hoped that there will be a good attendance of the younger technicians. The cost of meals and sleeping accommodation will be approximately 35s. and there will be a small registration fee.

Accommodation for part of the time can be arranged, and meals will be available for those not requiring sleeping accommodation.

All enquiries should be addressed to Dr. K. J. Irvine, Department of Metallurgy, The University, Leeds, 2.

Personal News

THE Ministry of Supply announces that MR. KENNETH GORDON, C.B.E., M.C., has been appointed Director-General of Ordnance Factories. Mr. Gordon, who is 55, has been specially released for this purpose by Head Wrightson & Co., Ltd., who only last November appointed him Deputy Managing Director of Head Wrightson Processes, Ltd., and the Ministry acknowledges their generous action in making him available. Previously Mr. Gordon was Joint Managing Director of the Billingham Division of Imperial Chemical Industries, Ltd. for 12 years, and Managing Director of Trinidad Leaseholds, Ltd., for two years.

DR. D. V. ATTERTON has been appointed by Foundry Services, Ltd., to the newly established post of Research and Development Manager. For the past two years, he has been engaged on fundamental research on foundry problems sponsored by the Research and Development Division of the British Steel Founders' Association.

MR. H. E. WRIGHT retired from the position of General Manager of the Steel, Peech and Tozer Branch of The United Steel Cos., Ltd., at the end of last month. Mr. Wright joined the Company 38 years ago at their Appleby-Frodingham Branch and has been with Steel, Peech and Tozer since 1925. He is remaining with The United Steel Cos., Ltd., in a consultative capacity, and will continue to serve on the Boards of the associated companies of which he is at present a Director. In addition, he is to supervise the development of Commercial Research at the Head Office. MR. ANDREW JOLLIE, who was General Works Manager, succeeds Mr. Wright as General Manager of Steel, Peech and Tozer, and MR. G. E. D. HALAHAN, who was Chief Labour Superintendent of The United Steel Cos., succeeds Mr. Jollie as General Works Manager.

MR. H. T. WORDSWORTH has retired from the post of General Manager of Sanderson Bros. & Newbould, Ltd., Sheffield, on the grounds of ill health, but remains on the Board. MR. J. R. A. BULL, formerly Sales Director, is appointed Managing Director.

THE Directors of Johnson, Matthey & Co., Ltd., announce the appointment of MR. E. G. PICKERING as a Joint Managing Director of the Company, as from 1st July, 1952.

MR. F. R. HEAD, J.P., A.M.I.I.A., has been appointed Manager of the new Lea Works, Luton, of George Kent, Ltd. He was formerly Production Controller at the firm's Biscot Road Works in Luton.

MR. R. H. HOUSTON retired from the position of Managing Director of The Thermal Syndicate, Ltd., at the end of June. He is succeeded by MR. F. J. EDWARDS.

MR. W. YOUNG, formerly Sales Manager (Foundry) of Clyde Alloy Steel Co., Ltd., has resigned his position to join Foundry Services, Ltd., as a Technical Representative in the Scottish area.

AFTER serving the British Thomson-Houston Co. for some 44 years, MR. A. G. SALISBURY retires from the Motor Engineering Department at the end of this month. Mr. Salisbury was a pioneer in fractional horse power motor development.

IN the course of a recent visit to India and Pakistan on a survey of export possibilities, MR. L. A. C. BARTLETT, Commercial Director of George Kent, Ltd., called at Bombay, Delhi, Lucknow, Karachi and Istanbul (Turkey).

MR. H. E. JACKSON, Chairman of the Metals Division of Imperial Chemical Industries, Ltd., has been elected President of the British Non-Ferrous Metals Federation. He was previously Vice-President of the Federation, and is a Member of the Regional Council, Federation of British Industries and a Past-President of the Aluminium Development Association.

MR. D. M. LEWIS has left the Research and Development Division of the British Steel Founders' Association, where he was Information Officer, to go to Aluminium Laboratories, Ltd., Banbury, as a Senior Investigator. He is succeeded by MR. W. E. FULLER who was, for a number of years, engaged in a similar capacity by the Road Research Laboratory of the Department of Scientific and Industrial Research.

MR. R. C. CROSS has resigned his position as Foundry Manager and Chief Metallurgist with David Brown-Jackson, Ltd., Salford, Manchester, to take up a new appointment with Foundry Services, Ltd., in connection with future developments of the Company in South Africa.

The Late Col. W. C. Devereux

IT is with regret that we record the death at Ascot on Saturday, June 21st, of Col. W. C. Devereux, C.B.E., one of the outstanding figures in the light metal industry.

Born in March, 1893, Col. Devereux was educated at King Edward's Grammar School, Aston, Birmingham, and during the First World War he was Superintendent of National Aircraft Factory No. 1. Subsequently, realising the forthcoming importance of forged aluminium alloys, he formed High Duty Alloys, Ltd., in 1927, to carry out research and development leading to the commercial production of the new high strength alloys needed for the aircraft industry. The quality of the achievements were reflected by the success of the Battle of Britain aircraft.

In 1945, conscious of the great strides taken by the aluminium industry and the need for a more broadly based organisation, he founded the Associated Light Metal Industries Group, spanning the industry from raw material to finished product. During the past seven years, this organisation has undertaken the manufacture of some of the most outstanding applications of aluminium yet conceived, including the aluminium roof structure for the Dome of Discovery.

Holding that progress in light metal development rested principally on research, Col. Devereux always employed a high proportion of research workers. After the war, he also broadened the base of his research activities by founding the Fulmer Research Institute, at Stoke Poges, to meet the urgent needs of industry for laboratories which would carry out research on a sponsored basis for individual companies. A new venture for this country, this was, perhaps, one of his most enlightened actions, and it was strongly supported by the late Sir Stafford Cripps.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Anti-Corrosive Coatings

THE widespread use of coal as a fuel results in the release of an appreciable quantity of sulphur dioxide into the atmosphere, and this factor has a considerable bearing on the corrosion of metals. It has been found, for instance, that iron and steel tend to rust more quickly in urban areas than they do in rural areas. To-day, when steel is not quite so plentiful as everyone would wish it to be, it is more than ever essential that these materials should be successfully protected from corrosion, and interest in this connection may be found in recent developments of Detel Products, Ltd., pioneers of chlorinated rubber coatings as a medium of protection for almost every type of surface.

The new Detel coatings consist of chlorinated rubber and other synthetic resins of a similar character dissolved in a mixture of high-flash aromatic hydrocarbons (100° F.) in which is ground a suitable pigment. The paint or coating dries by evaporation, and not by oxidation, so that drying is more rapid than that of oil or even synthetic paints, and has the attractive appearance of a lacquer. Most pigments can be ground in Detel medium as it is very inert and will protect sensitive pigments from the action of acids or alkalies. The best protective compositions, however, are made with highly-resistant pigments such as titanium dioxide.

Detel coatings can be classed into two groups, the first protects by reason of its impermeability and general resistance to corrosive agents and the second because of the chemical composition. The former is used mainly on plaster, wood, metal or cement and is completely resistant to chemical attack. Where the surface needing protection is either iron or steel, the second type is used and is known as Detel Metal Undercoat (D.M.U.) and requires a top coat for finishing off. This undercoat depends mainly on its high metallic zinc content (over 96%) for its protection of these materials.

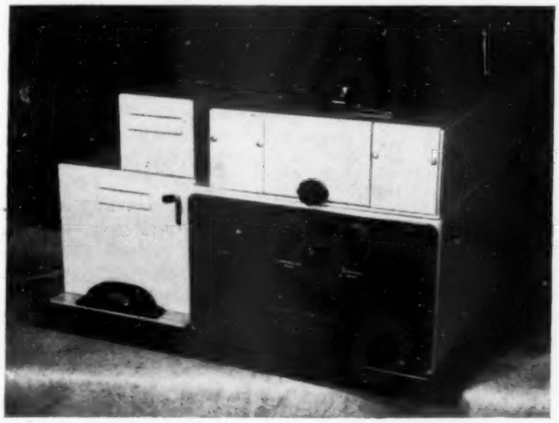
There are, of course, many excellent methods of protecting steelwork but most of them are expensive in use, especially where, for example, large areas have to be covered and in many cases it is impossible to protect difficult and inaccessible surfaces except by painting. D.M.U. can easily be applied with a brush and when dry any top coat of good oil or synthetic paint can be used and corrosion creep under apparently sound paint cannot occur. It was first used extensively as a marine anti-corrosive in 1936 and its use greatly increased during the war. It is now equally efficient in the general industrial field and is successfully protecting plant in factories, sewage, water and chemical works, and plating and de-scaling shops.

Especially interesting is its use in magnesium foundries, where corrosive attack is known to be particularly severe because very considerable volumes of sulphur dioxide are evolved during casting, and a thick layer of hygroscopic dust is deposited on all flat surfaces, keeping them continually warm and acid. The specification for structural steel in these circumstances is one coat of D.M.U. and two coats of Detel Red "A." This specification is of very wide application as it combines the steel and iron protecting properties of D.M.U. with the high acid, alkali and water resistance of Grade "A" Detel. Many engineering firms are solving their storage problems by coating their castings with D.M.U. immediately on receiving them from the foundry and then storing them in the open.

Detel Products, Ltd., South Ruislip, Middlesex.

Baldwin Absorptiometer

THE Baldwin absorptiometer represents a newly developed instrument for the measurement, by means of vacuum photocells, of extinction coefficients of liquids in any region of the visible and near infra-red spectrum. As a result of the attention paid to universality of application, combined with simplicity of operation, it is equally suitable for use as a process control instrument in an industrial laboratory and as a tool for research work.



Built on the unit principle, a common base plate carries the optical unit and the light source housing. The latter is interchangeable, allowing use of either tungsten lamp or discharge tube as source of illumination. The optical unit incorporates focusing lens, a beam splitting device to yield a measuring and a compensating beam, wavelength selector, neutral wedge intensity controls, sample cell holder and measuring and compensating photocell.

Continuous wavelength selection is provided by means of a novel type of metal-dielectric interference filter, incorporating a wedge-shaped dielectric film. The wavelength of peak transmission is thus a function of the position of the filter, so that the filter acts like a monochromator. The mounting of the filter is such that one unit can be replaced by another in a few seconds. Each filter mount carries a scale, calibrated in wavelengths, visible through a window in the instrument case.

A slit of adjustable width is mounted directly in front of the interference filter, and allows control of the width of the passband for special applications. Filter sets consisting of a series of monochromatic filters can be substituted for the interference wedge, and provision for

insertion of three additional filters of the glass, gelatine or interference type is made.

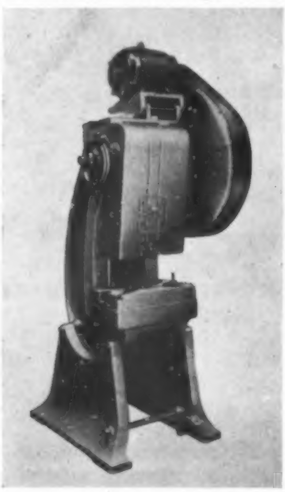
The beam splitting device allows use of either a semi-transparent aluminized mirror, or an all dielectric interference filter type of neutral beam splitter. The compensating beam produced by it serves to minimise errors due to light source fluctuations, and can be used in both null-balance and off-balance (deviation) methods of measuring extinction.

The cell carrier accommodates sample cells, of different cross-sections, including micro-cells, and optical path length can vary between 0 and 10 cm. Instantaneous interchange of sample and blank or standard cells is easily effected, and the cell carrier is made of acid-resistant material, easily removed for cleaning. The output from the photocells is fed into a balanced electronic amplifier, and the difference in photo-current-indicated on a robust 4-in. microammeter. This meter is of a special construction yielding an extinction scale which is practically linear over almost the total range. The linearity and stability of the amplifier are of a very high order.

Baldwin Instrument Co. Ltd., Dartford, Kent.

Inclinable Power Press

THE new Besco Production Inclinable Power Press, Model B.A. Mark II, has a range of three sizes with the stroke adjustable from $\frac{3}{8}$-in. to $1\frac{7}{8}$ in. in the smallest and to $2\frac{3}{8}$ in. and $2\frac{3}{4}$ in. in the two larger machines respectively. Exerted pressures vary between 10, 18 and 28 tons according to size.



The design is based on a press with a high reputation for reliability and ease of operation. The body member has been carefully constructed to meet every general purpose in the field of modern medium press work, the permissible working stress embodies a high safety factor and sections under stress have a proper distribution of metal, though care has been exercised in avoiding unnecessary weight.

The ram is of generous proportions with adjustable vee gibs, ample in length to obviate deflections and ensure a maximum efficiency and working life for tools and dies. The sizes of the ram faces over the vee slides are $7\frac{3}{4}$ in. with a $1\frac{1}{2}$ in. diameter tool hole in the ram, for the B.A. Mark II, No. 18 and 9 in. and $9\frac{3}{4}$ in. with 2 in. diameter hole in models 19 and 20. The connection between pitman and slide is by buttress threaded ball end type screw, manufactured from a high carbon chrome steel and subjected to heat treatment.

Both bed and bolster are tee slotted and clamps are fitted for holding dies. The left to right, by front to back measurements of the beds, for the three machines, are: 16 in. × $9\frac{1}{2}$ in., $19\frac{1}{2}$ in. × $11\frac{1}{2}$ in., and $22\frac{1}{4}$ in. × $13\frac{1}{2}$ in., with holes for the delivery of pressings measuring 8 in. × 6 in., 9 in. × 7 in., and $10\frac{1}{2}$ in. × 8 in. The bolsters are $1\frac{3}{4}$ in., $2\frac{1}{2}$ in., and $2\frac{3}{4}$ in. thick.

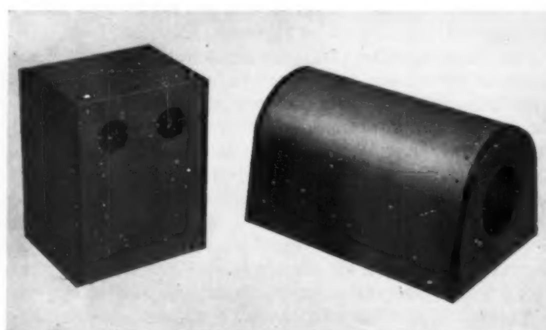
Each crankshaft is a nickel-chrome-molybdenum forging, heat treated, of sufficient strength, diameter and bearing lengths to withstand the imposed loads. A spring-adjusted friction damper is fitted to prevent over-running, and a safety pawl prevents reversal.

A clutch, of the roller-key type, presenting a long backed up surface to engage with the shaped seating in the flywheel gear, is fitted to all machines in the range and these are designed to permit single stroke operation or continuous working. When set for single stroke the press will make one stroke only even though the operator keep his foot on the treadle. The change-over to continuous operation is quickly and easily effected.

F. J. Edwards, Ltd., 359-361, *Euston Road, London, N.W.1.*

High Temperature Combustion Tube Furnaces

A RANGE of high temperature furnaces designed to take up to a $1\frac{1}{4}$-in. O.D. combustion tube, has been developed by Gradec, Ltd., to meet the need of those who require a small tube furnace which can exceed the maximum temperature of the normal wire-wound type and has an exceptionally rapid heating up time. The normal maximum operating temperature is 1,400° C., but these furnaces may be used up to 1,500° C. occasionally at the cost of shortening the life of the silicon carbide rods.



The furnace proper is cylindrical in shape and is housed in a dome shaped casing, attractively finished in black and silver enamel, mounted on rubber feet. The heating chamber is 7 in. long and 3 in. diameter, and is made up of a fused alumina tube held in place by two refractory end pieces and insulated by a high grade refractory insulating aggregate, so as to keep the heat losses down to a minimum. Provision is made for the silicon carbide heating rods to pass through the heating chamber, the ends protruding beyond the end pieces so as to be in cool air. The casing is fitted at each end with easily removable discs which give access to both ends of the heating rods so that these may be easily fitted and replaced when necessary.

The furnaces are made in two- and four-rod types with 1 kW. and 2 kW. ratings, respectively (2 kW. and 4kW. starting peaks). A range of wall mounting control cubicles is also available to provide compensation for the ageing of the silicon carbide rods and to obtain the maximum possible life.

Gradec, Ltd., 96, *Hackney Road, London, E.2.*

CURRENT LITERATURE

Book Notices

THE COLD WORKING OF NON-FERROUS METALS AND ALLOYS

Institute of Metals Monograph and Report Series No. 12. 206 pp., numerous illustrations. Published by the Institute of Metals, 4, Grosvenor Gardens, London, S.W.1. 15s.

THIS volume contains the five papers presented at the Institute of Metals Symposium on the Metallurgical Aspects of the Cold Working of Non-Ferrous Metals and Alloys, held in London on the occasion of the Annual General Meeting of the Institute, March 14th, 1951, together with the discussion which took place on that occasion.

The first paper, by Dr. M. Cook and Dr. T. L. Richards, deals with the fundamental aspects of the cold working of metals. After reference to the nature of the metallic state, a brief outline is given of several mechanisms involved in plastic deformation, including crystallographic slip, twinning, kinking, and a shear mechanism to which particular attention is drawn because of its importance in many metal-fabrication processes. The influence of plastic deformation on structure is described with special reference to the development of preferred orientation in view of its technological significance, while the effect of deformation on the fine structure, as revealed primarily by X-ray diffraction studies, is considered in terms of the dislocation theory. The relation of work-hardening and plasticity to the structural changes brought about by cold working is also discussed.

The remaining four papers deal with technological aspects of the subject. In the first, Mr. S. F. Chisholm considers the question of lubricants for the cold working of non-ferrous metals. Although non-ferrous metals have been cold worked for many years, no greater lack of uniformity exists in any of the varied processes employed than in the selection and application of the forming lubricants. Mr. Chisholm discusses the processes of cold rolling, press drawing, tube drawing, and wire drawing, from the point of view of the demands they make on lubricants, and suggests suitable types of lubricant in each case.

After reviewing recent progress in rolling practice, Mr. C. E. Davies describes the modern techniques employed in rolling: (a) copper and its alloys, and (b) aluminium and its alloys. The relative merits of two-high and four-high mills for various purposes are discussed, as are those of reversing, non-reversing and tandem units. Reference is made to the latest designs for mills with minimum work-roll diameters, such as the Sendzimer mill, and consideration is given to the auxiliary equipment required to handle sheet and strip during rolling.

Mr. F. T. Cleaver and Mr. H. J. Miller review the principal landmarks in the development of the wire-drawing industry prior to describing present-day machines, including tandem- and cone-type machines, in which slipping of the wire occurs in the course of drawing, and also the non-slip variety. Die design, die materials, lubricants, speeds of drawing, reductions, and other aspects of wire drawing are covered, and a detailed account is given of the current practice in the production of copper, brass, bronze, and other copper alloy wires, and also of light alloy wires. Various types of defects encountered in wire are also considered.

The last paper, by Dr. J. D. Jervons, deals with both deep drawing and pressing. The terms "sheet and strip" and "deep drawing and pressing" are discussed, and various methods of deep drawing and pressing are described. Crank and hydraulic actuation of presses are compared, and attention is drawn to certain merits of multi-punch presses. Tool materials and drawing lubricants are referred to, and inter-stage annealing is discussed in relation to the faults commonly experienced under industrial conditions. In considering the properties of sheet which determine its behaviour under the press, the usefulness of ordinary and special tests in predicting such behaviour are discussed. Finally, the behaviour of those non-ferrous metals which are commonly deep drawn and pressed is described.

A GUIDE TO FILTER PAPER AND CELLULOSE POWDER CHROMATOGRAPHY

Compiled by J. N. Balston and B. E. Talbot, and edited by Tudor S. G. Jones. 155 pp. Published by H. Reeve Angel & Co., Ltd., London, and W. & R. Balston, Ltd., Maidstone. 1952. 8s.

IT is steadily becoming apparent that paper chromatography has immense possibilities as a tool in chemical analysis and research. Moreover, this is one of the few modern forms of instrumentation that is both cheap and relatively simple to operate. The present book is intended to introduce the reader to the technique and scope of filter paper and cellulose powder chromatography, and to serve as a general reference book to the principal papers published on this subject. The first part is devoted to a description of the methods and materials employed in this particular branch of chromatography. The second and larger part deals with its use in the separation of numerous organic and inorganic compounds. Amino acids, sugars, amines, phenols, alkaloids and dyestuffs are among the organic compounds discussed. The section devoted to inorganic cations and anions includes methods for separating the constituents of such mixtures as silver, mercury and lead; iron, aluminium and chromium; and tin, arsenic and antimony. The book is well-produced and the price for the paper-backed copy is very moderate. There are numerous references to the literature.

STATISTICAL YEAR BOOK FOR 1951. PART I.—UNITED KINGDOM STATISTICS

Published by the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1. 7s. 6d.

THIS volume gives information concerning the U.K. iron and steel industry in all its aspects. Besides iron and steel production, finished steel deliveries and the use of raw materials, the tables give details regarding imports and exports, prices, stocks and employment in the industry. They are grouped according to subject, beginning with iron ore and working through the various sections of the industry to the overseas trade statistics.

For the convenience of the general reader, two summary tables included at the beginning give information for a long run of years. The first brings together the main statistical series relating to iron ore, coke, pig iron, scrap and steel. The second sums up the information regarding the supply and disposal of steel. It shows, for example, that the supply of steel available for consumption in the United Kingdom (excluding exports) rose from an annual average of 5,050,000 ingot tons in 1921–25 to 9,240,000 tons in 1938 and to 14,500,000 tons last year.

Trade Publications

"A Complete Service in Industrial Heat Engineering" is the title of Bulletin V10B recently issued by the Incandescent Group which comprises seven specialist companies, each responsible for its own research, design and construction. Frequent interchange of data enables members of the Group to give expert advice on any phase of industrial heat engineering. The range of plant detailed and illustrated is extremely wide, covering as it does various types of gas-fired furnaces; salt baths; gas atmosphere generators; gas producers; foundry cupolas and accessory equipment; melting furnaces; and ovens for core drying, stoving, tin-printing, low-temperature heat treatment, etc. On the electrical side there is a range of electric resistance furnaces; direct-arc steel melting furnaces; high frequency induction heaters; and dielectric core-baking units. Another member of the Group provides a complete vitreous, enamelling service, including furnaces, pickling plant, spray booths and enamelling materials. Finally the Group includes a company specialising in the manufacture of a complete range of heat-resisting alloy castings for parts subject to high temperatures.

The Cambridge Instrument Co., Ltd., have recently published the fourth in a series of monographs dealing with the association of prominent men of science with the Company. The object of these monographs is to place on record the indebtedness of instrument makers, and indeed of the whole world, to these men of science, and to detail the story of their collaboration before time blots it from memory. The present publication covers the fascinating story of the cloud chamber devised by Professor C. T. R. Wilson for rendering visible, and photographing, the tracks of ionising particles, once described by the late Lord Rutherford as "the most wonderful experiment in the world."

We have received from Edgar Vaughan & Co., Ltd., Legge Street, Birmingham, 4, an interesting little booklet dealing with the quenching of steel. The object of the publication is to outline the changes which take place in steel during the heat treating process and the relationship of these changes to the resulting physical properties of the steel. In these notes, the importance of the quenching operation itself is given special stress, particular attention being paid to quenching practice and to quenching media, including water, oil and the salts used in isothermal treatment. Mass production and the wider use of alloy and plain carbon steels have led to considerable improvement in the production and application of quenching media, and the facts given are the result of much research, supplemented by many years of actual practice in heat-treatment plant.

Birlec Limited have recently published a four-page brochure (Birlec Publication No. 39, revised) which deals, in very general terms, with the complete range of their products. These include both electric and gas fired heat treatment furnaces, arc and induction melting furnaces, induction heating equipment for both forging and heat treatment applications, and Birlec Lectrodryers for drying compressed air, process gases, etc., and maintaining low atmospheric humidities. One page of this brochure is devoted to Birlec melting furnaces which are installed in steel works, ferrous and non-ferrous foundries, die casting shops, etc., throughout the world. This two-coloured publication, which is generously illustrated, is available on application to Birlec Limited, Tyburn Road, Erdington, Birmingham, 24.

Books Received

"Polarized Light in Metallography." Edited by G. K. T. Conn and F. J. Bradshaw. Prepared for the Optical Methods Sub-Committee of the British Iron and Steel Research Association. 130 pp. inc. 51 illustrations. London, 1952. Butterworths Scientific Publications in conjunction with B.I.S.R.A. 21s.

"Progress in Metal Physics." Vol. III. Edited by Bruce Chalmers, D.Sc., Ph.D. 334 pp. inc. indices. London, 1952. Pergamon Press, Ltd. 48s.

"An Engineer's Approach to Corrosion" by C. F. Trigg, M.Sc., A.M.I.C.E., A.M.I.Mech.E. 133 pp. inc. index. London, 1952. Sir Isaac Pitman & Sons, Ltd. 15s. net.

"Practical Radiography for Industry," by H. R. Clauser. 301 pp. inc. index. New York, 1952. Reinhold Publishing Corporation. Obtainable in this country from Chapman & Hall, Ltd. 60s. net.

"Foundry Work," by Edwin W. Doe. Prepared in Co-operation with The Textbook Committee of the Educational Division, American Foundrymen's Society. 109 pp. inc. 96 illustrations, glossary of foundry terms, and index. New York and London, 1951. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 14s. net.

"Proceedings at a Symposium on Welding and Riveting Large Aluminium Structures" held in London in November, 1951. 223 pp. London, 1952. The Aluminium Development Association.

"Conference on Malleable Cast Iron" held at Ashorne Hill, March 14th to 16th, 1951. 193 pp. Alvechurch. 1952. The British Cast Iron Research Association.

"Annuaire de la Métallurgie du Rhone, 1951–52." Edité par la Société Métallurgique D'Edition." 271 pp. Lyon, 1952.

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LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

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The Spectrochemical Analysis of Tungsten

By C. H. R. Gentry, B.Sc., F.R.I.C., and G. P. Mitchell, B.Sc.

For a number of applications of tungsten, it is essential that many impurities should not be present to an extent exceeding a few parts per million. The chemical methods available for the determination of these impurities are complicated and time-consuming, and a spectrochemical method is described in which a carrier-distillation technique is applied.

TUNGSTEN is typical of a group of elements, the refractory metals, which at the moment find limited but extremely important applications, in the construction of valves, lamps and other electronic devices. In the future it can be confidently predicted that this group of elements, which includes molybdenum, titanium, and tantalum as well as tungsten, will find a very much wider field of application in the manufacture of jet-type engines and in the construction of chemical plant. As the name implies, the refractory metals have properties such as chemical inertness, good hot-hardness, and low vapour pressures at high temperatures which are essential requirements of many modern engineering projects. A considerable amount of work is, therefore, being carried out on the manufacture, properties and application of these elements. Such work requires close analytical control not only of the finally produced metal but also of the various compounds intermediate in its processing. This paper is concerned with a particular method developed for the control of the manufacture of one of these elements—tungsten—but the principles of the method may be applicable to the other refractory metals and the procedure described is thought, therefore, to be of rather wider interest.

For the manufacture of tungsten wire with specified physical properties, it is known that many impurities must not exceed a few parts per million, and in some cases it is believed that freedom from much less than this is desirable. Published methods for determining these impurities are usually of a chemical nature and involve a rather long process requiring the use of many techniques and the employment of skilled analysts. In speed, sensitivity and routine-reliability such chemical methods of trace analysis cannot generally be expected to compete with spectrochemical methods.

However, the application of the spectrograph to the analysis of tungsten, containing impurities in the range from about 0·05% to as low a limit as possible (provisionally set at 0·0005%), presents certain fundamental difficulties. To detect such traces it is necessary to use some form of arc excitation, and tungsten, in common with other high atomic weight elements (the refractory metals, rare-earths, etc.), gives a very complex atomic spectrum, which can interfere seriously with the spectral lines of the impurity elements. Tungsten is characterised by a very rich line spectrum derived from a multiplicity of electron configurations in both the neutral and ionised atoms, and in the simple arc this can be further complicated by a heavy background given by incandescent particles of oxide. The ready volatility of tungsten trioxide and the low ionisation potentials of tungsten further enhance the tungsten spectrum at the expense of the impurities, which are less volatile in the arc or have higher ionisation potentials. It can be readily understood, therefore, that using simple arc procedures it is easy to miss 0·01% impurity, while in some cases even 0·1% may be below the limit of detection.

It is apparent that sensitive spectrochemical methods of general utility can be developed only by suppressing or otherwise avoiding the spectrum of the tungsten. A technique recently developed in the similar case of uranium-base materials[1] offers a method of achieving this aim. This technique is essentially a method of fractional distillation in the arc involving :—

(1) Conversion of the sample to a form of low volatility ;
(2) Addition of a small amount of a selected volatile carrier material ; and
(3) Partial distillation of the mixture in a D.C. arc under carefully controlled conditions.

It has been necessary to modify much of the detail of the original *carrier distillation* method, but its main principles have been retained in the present method for the analysis of tungsten. The success of the new technique is evident from a consideration of Fig. 1 which shows part of the spectra of tungsten oxide containing typical amounts of impurities taken by a simple arc procedure and by the present method.

Principles of the Method

The analytical control of tungsten manufacture may involve the examination of tungsten oxides, tungstic acids and various ammonium tungstates as well as the metal. It is convenient to base an analytical method on only one of these materials, and then to convert any of the others into this form prior to spectrochemical examination. An obvious choice in the present case is tungsten trioxide, which is obtained from any of the other substances by ignition in air without loss of any of the metallic impurities. The spectrographer's problem

1 Scribner, B. F. and Mullin, H. R., *J. Res. Nat. Bur. Stds.*, 1946, **37**, 379.

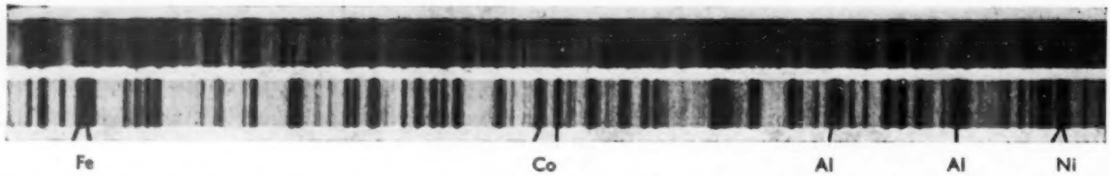

Fig. 1.—Spectra of a typical sample of tungsten trioxide obtained by a simple D.C. arc technique (A) and by the present technique. A comparison of the two spectra shows the virtual absence of the tungsten lines, the marked reduction of background, and the enhancement of the impurity lines in Spectrum B. Many of the extra lines in this spectrum are due to the added internal comparison element cobalt.

becomes simply the determination of the traces present in trioxide.

In addition to this main analysis of pure tungsten trioxide, a subsidiary problem is the examination of *doped* material. This arises from the practice of controlling the structure of tungsten filament wire, used in lamps or thermionic valves, by the addition of other substances, either to the tungsten trioxide before reduction to the metal or to the metal itself.[2] The substances added include, for example, the alkalies and silica in combination with each other or with other oxides. Only traces of these additions may be present in the finished wire, but the control of the extent of doping is essential. The analytical problem presented by doped material is essentially the same as that of the purer tungsten oxide, and the method has been designed to include the examination of such doped material containing up to 1% added potassium silicate.

The first requirement of the carrier-distillation method is for the material matrix to be in a form which is effectively non-volatile in the D.C. arc. In the case of tungsten, its carbide provides such a form, but to prepare it in a separate process prior to spectrochemical examination would be difficult and would involve very considerable danger of loss of some of the impurity elements. Fortunately, in the carrier distillation method, the electrode in which the sample is placed takes the form of a deep hole in a graphite rod. When the arc is struck this electrode rapidly attains a white heat, in fact it is conveniently referred to as the *furnace electrode*. By intimately mixing the sample of tungsten trioxide with carbon or graphite powder, it is possible to form the tungsten carbide *in situ*. The excess carbon present maintains an atmosphere of carbon monoxide which prevents oxidation back to tungsten trioxide. In this very simple manner the tungsten is converted to a form having a low volatility—satisfying the first requirement of the carrier-distillation method. The actual formation of tungsten carbide has been confirmed by an X-ray diffraction examination of a residue left in the furnace electrode.

It is pertinent to consider what happens to the impurities during the reduction of tungsten trioxide in the furnace electrode. In general, the heavy metal impurities, e.g., iron or nickel, will be reduced to the metal while some of the other oxides, e.g. of aluminium or calcium may be unaffected. The spectra of such impurities will be but little suppressed as compared with tungsten. However, molybdenum, which closely parallels tungsten, will be converted in an analagous manner to a relatively non-volatile form. Fortunately, the amount of molybdenum normally present in tungsten compounds is of the order of 0·1%, i.e. much more than the traces of the other impurities, so that despite the partial suppression of its spectrum, an analysis for molybdenum is still possible.

An essential feature of the carrier-distillation procedure is the presence of an added material—the carrier—whose function is to sweep out slowly the minute quantities of impurities volatilised by the heat of the excitation, thereby effecting a sharp separation from the more refractory matrix. Simultaneously, the carrier assists in the stabilisation of the arc. It should be a stable and inert substance which can easily be ground with the samples ; it should be free from traces of the elements to be determined and it should have a volatility and an ionisation potential intermediate among these elements. Silver chloride, as recommended by Harrison and Kent,[3] has proved satisfactory in the present work.

As well as the carrier it is necessary, for an accurate determination, to incorporate very much smaller percentages of further internal control elements. For the determination of most of the impurities, cobalt—an element rarely if ever found in tungsten—has been used. The graphite powder, carrier and internal control element are conveniently mixed together so that the sample preparation consists simply in mixing the tungsten trioxide with this *base mixture*. After grinding in an agate mortar, the final analysis mixture is packed into the deep cup in the furnace electrode. The other electrode is a pointed graphite rod.

When an arc is struck, there is an initial period of rather less than 5 seconds in which the arc burns erratically, during which period the furnace warms up and the reduction to tungsten carbide takes place. At the end of this initial period, carrier distillation commences and the arc then runs quietly and steadily for about 30 seconds, changing at this point to the initial unsteady state. In the steady period, the arc is maintained by the distillation of the carrier, and the greater part of the impurities volatilises into the arc stream. Exposure for part of the steady period is used for the determination of most of the impurities, the only exceptions being the alkali metals. Falling plate studies have shown that these volatilise to a considerable extent during the initial period before the arc becomes steady ; it is necessary, therefore, to expose for this initial period as well as part of the steady period when examining for sodium and potassium.

Standard Samples

Success of the spectrochemical method was entirely dependent on obtaining suitable standard samples. As a wide range of accurately analysed samples was not available, it was necessary to make a range of standards by adding known amounts of impurities to very pure

2 Smithells, C. J., "Tungsten," 2nd Ed., 1945.

3 Harrison, G. R. and Kent, R. (Publication pending. Manhatten Project Technical Series). Given in ref. 1.

tungstic oxide. So-called "spectrographically-pure" tungsten, available commercially, contained too much impurity for the present purpose, so the further purification of the best available tungsten trioxide was undertaken. After repeated purifying treatment some tungsten trioxide was obtained which contained much less than 0·001% of all metallic impurities with the exception of silicon. This material was used for the preparation of all the standard samples.

The first step was the manufacture of a standard, designated as a "1% master mix" containing a known amount, approximately 1%, of each of the impurities. This was done by adding to 10 gms. of the pure tungstic oxide in a platinum dish the requisite amounts of solution of the impurities, viz. an *aqua regia* solution of iron, nickel, copper, aluminium and molybdenum, a hydrochloric acid solution of tin and solutions of sodium hydroxide and potassium dichromate. The mixture was evaporated to dryness, ignited at ca. 600° C. under oxidising conditions and then finely ground in an agate mortar. Five standards were prepared by grinding some of this mixture with the appropriate weights of the pure tungstic oxide. Two further standards containing larger amounts of molybdenum, and three containing larger amounts of the alkalis and silica were also prepared. The composition of these standards is shown in Table I.

TABLE I.—STANDARD SAMPLES

Standard	% Al, Cu, Fe, Ni, Sn	% Cr	% Na	% K	% Mo	% Si
A	0·0012	0·0015	0·0012	0·0012	0·0012	—
B	0·0032	0·0042	0·0032	0·0032	0·0032	—
C	0·0061	0·0081	0·0061	0·0061	0·0061	—
D	0·0104	0·0140	0·0104	0·0104	0·0104	—
E	0·051	0·068	0·051	0·051	0·051	—
F	—	—	—	—	0·100	—
G	—	—	—	—	0·300	0·05
H	—	—	—	0·50	—	0·100
I	—	—	0·20	0·20	—	0·250
J	—	—	0·10	0·10	—	0·600

Final Technique

The final method was comparatively simple, but it was based on a systematic investigation of the several factors involved; this was essential in order that the variations permissible in routine practice should be known.

Preparation and Purification of Electrodes

Preliminary experiments showed that the machining of the graphite electrodes introduced significant amounts of copper and iron. A purification treatment after machining was therefore necessary—advantage was taken of this to use graphite rods of a grade slightly lower than those of the highest commercial purity, with a very considerable saving in cost.

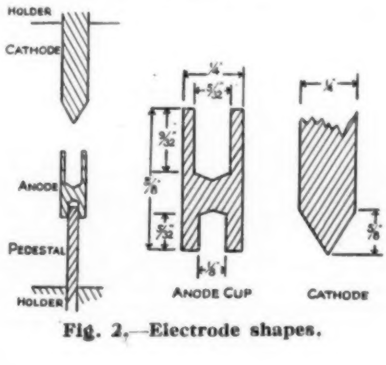

Fig. 2.—Electrode shapes.

The electrodes used are shown in Fig. 2; the anode or furnace electrode is very similar to that of Scribner and Mullin, but the cathode differs slightly. Initially, special tools were used to form these electrodes, but eventually the use of a lathe was found to be more rapid and less liable to break the rods.

After machining, a batch of the electrodes is purified by a continuous extraction procedure in an apparatus of the Soxhlet type, previously thoroughly cleaned. After continuous extraction for 48 hours with AnalaR nitric acid, a distilled water extraction for a further 12 hours is made in the same apparatus. The electrodes are then dried in a covered Petrie dish at 140° C. After this procedure, the electrodes are stored in covered glass dishes until required, and are then handled with stainless-steel tweezers.

Preparation of Samples

If the sample is not received in the form of trioxide, an ignition is carried out in oxygen. The change in weight in the ignition is recorded in order that the spectrochemical results, expressed as the percentage element impurity in tungsten trioxide, can be converted to percentage impurity in the sample as received. Equal weights, approximately 0·2 g. of the tungsten trioxide and the base mixture are thoroughly ground together in an agate mortar. The base mixture consists of graphite containing 6% silver chloride and 0·1% cobalt as nitrate; it is prepared by mixing the correct volumes of standard silver nitrate and cobalt nitrate solutions with graphite, adding an excess of hydrochloric acid, evaporating to dryness, drying at 140° C. and regrinding in an agate mortar.

To fill the furnace electrode, a portion of the mixture is taken with the aid of a special platinum scoop, designed to hold 40 mg., and placed in the electrode cavity. On gently tapping the electrode the mixture settles down, filling approximately half the cavity. Four such electrodes are prepared for each sample.

Spectrographic Conditions

The Hilger large Littrow quartz spectrograph is used. The analysis for most of the impurity elements is carried out using an Ilford Thin Film Half Tone plate over the wavelength region 2,700–4,100 Å, and a further analysis, for sodium and potassium only, is made on an Ilford Long-Range Spectrum Plate using a waveband of 3,300–8,000 Å.

The arc stand is set so that the source is 38 cm. from the slit, with a lens so placed that it throws an image of the source at or near the collimating lens; this ensures uniform intensity along the spectrum line length. A two-step rotating sector is placed between the source and the lens in order that each spectrum shall consist of two parts, the one representing the total light intensity received at the plate, and the other 10% of this. In this manner, certain elements, particularly copper and silicon can be determined in the main analysis (vide infra).

The electrodes are set with a separation of 4 mm. as shown in Fig. 2 with the bottom electrode connected to the positive side of a D.C. generator. The current during arcing is manually maintained at 10 amperes. For the main analysis a preburn period of 5 seconds is allowed prior to an exposure of 25 seconds, while for the determination of the alkalis a direct burning time of 25 seconds is used. All samples are recorded in duplicate. Plate processing follows standard recommended practice.

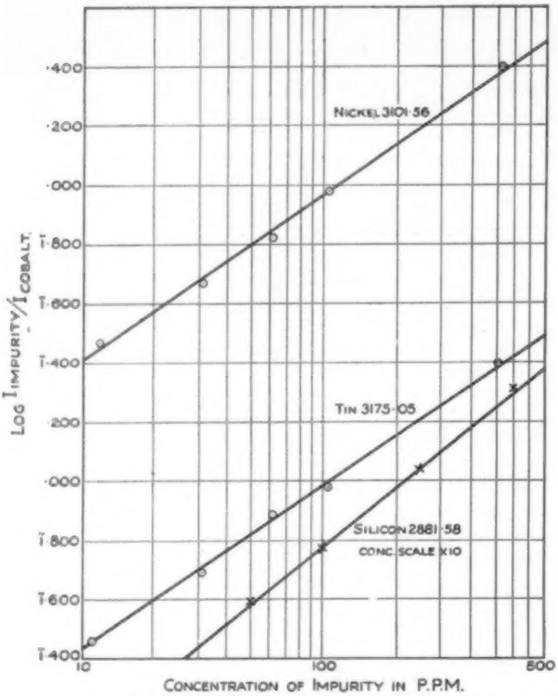

Fig. 3.—Working curves for nickel, tin and silicon in tungstic oxide.

To conserve the standard samples and to save time, spectra of the standards in duplicate are recorded together with an emulsion calibration pattern at approximately monthly intervals. The analysis of an unknown therefore consists of recording the spectra in duplicate under standard conditions, together with an emulsion calibration pattern, and referring the measured intensity ratios to the standard working curves. Typical working curves for the representative elements nickel, tin, and silicon are shown in Fig. 3.

Plate Reading

Photometry of the exposed plates is made on a Hilger densitometer ; the usual procedure being followed. For the general analysis of tungstic oxide the following elements are determined on the Ilford Thin Film Half Tone plate covering the waveband region 2,700 Å–4,100 Å—nickel, iron, tin, chromium, copper, aluminium, molybdenum, silicon, and sodium, the latter in the higher percentage range. Under the normal conditions of analysis, both copper and silicon are extremely sensitive and the lines of these elements are photometered in the reduced step of the recorded spectrum and compared with a line in the first step of the spectrum. Table II records the conditions for photometry of the plate.

TABLE II.—LINES USED IN THE PHOTOMETRY

Element	Wave-length of Line Used—Å	Method	Range %	Precision %	Sensitivity p.p.m.
Cobalt reference in all cases	3072·34	—			
Nickel ..	3101·56	Photometric 1st step	0·001–0·05	± 6	1
Iron ..	3021·08	Photometric 1st step	0·001–0·05	± 10	5
Tin	3175·05	Photometric 1st step	0·001–0·05	± 10	5
Chromium	3021·57	Photometric 1st step	0·001–0·05	± 5–10	5
Copper ..	3247·54	Photometric 2nd step	0·001–0·05	± 10	0·5
Aluminium	3082·16	Photometric 1st step	0·001–0·05	± 5	1
Molybdenum	3132·59	Photometric 1st step	0·01 –0·3	± 20	10
Sodium ..	5889·9	Comparison with background.	0·001–0·05	± 10	1
Potassium	7664·9	Comparison with background 2nd step.	0·002–0·5	± 15	5
Silicon ..	2881·58	Photometric 2nd step	0·001–0·6	± 10	0·5

It is to be noted that a separate exposure under the conditions already stated is made for the determination of sodium and potassium, and that the appropriate line second spectrum step is compared with the adjacent background of the spectrum.

In the case of calcium and arsenic a visual examination of the sensitive lines is made if required.

Results

The complete method as given in this paper has been checked by the spectrographic analysis of synthetically prepared samples, and it is from these results that the precisions quoted in Table II have been obtained. Of more interest, however, is the comparison of the spectrographic and chemical methods of analysis. A sample of tungsten metal in powder form was used as an inter-laboratory standard and has been chemically analysed independently by two laboratories using referee methods.

The results of these analyses are given in Table III.

TABLE III

Impurity	Analysed by		
	Lab. 1	Lab. 2	Spectrochemical
Fe %	0·027	0·024	0·028
Ni %	0·0006	0·0010	0·0009
Cu %	0·0003	0·001	0·0003
SiO_2 %	0·33	0·32	0·29
Mo %	0·36	0·29	0·40
Cr %	0·001	—	0·0010
Al %	0·007	—	0·010
Cu %	0·0003	—	0·0003
Sn %	—	—	0·006
Na_2O %	0·012	—	0·011
K_2O %	0·26	0·32	0·27

From this example, the difficulty in obtaining reproducible chemical results may be judged, and the agreement between the average results and the spectrographic figures is indicative of the value of the spectrochemical method.

As a further check on the method, samples were analysed over a period by the spectrograph and by routine chemical methods. A few, typical, results are given in Table IV.

From the results quoted in Tables III and IV there can be no doubt that the results of spectrochemical analysis are in reasonable agreement with those of the chemical methods. As a routine method it is much easier and more accurate than routine chemical analysis. A good example of this is the case of tin which is very simply estimated spectrochemically, but has required the development of a new method[4] before satisfactory chemical results could be obtained.

Discussion

In the introduction to this paper, several factors were mentioned as desirable features of a method of analysis for tungsten ; they included speed, sensitivity, precision and reliability. It is worth while considering how far the present method has achieved these aims.

In speed it can be said that the spectrochemical method completely overshadows the chemical method. On a routine base, one spectrochemist can analyse 10

[4] Gentry, C. H. R. and Sherrington, L. G., *Analyst*, 1950, **75**, 17.

TABLE IV.—COMPARISON OF SPECTROGRAPHIC AND CHEMICAL RESULTS

Sample No.	Method of Analysis	% Fe	% SiO_2	% Al_2O_3	% Cu
5	Chemical	0·008	0·34	0·004	—
	Spectrographic	0·0083	0·43	0·0062	0·0019
71	Chemical	0·007	0·52	0·004	—
	Spectrographic	0·0119	0·49	0·009	0·0025
37	Chemical	0·012	0·55	0·003	0·002
	Spectrographic	0·0101	0·49	0·0072	0·0019
27	Chemical	0·011	0·34	0·007	0·002
	Spectrographic	0·0122	0·37	0·0062	0·0031
75	Chemical	0·011	0·50	0·004	0·002
	Spectrographic	0·0114	0·56	0·0062	0·001
69	Chemical	0·011	0·51	0·005	0·007
	Spectrographic	0·0112	0·52	0·009	0·007

samples each for 10 impurities in an 8½ hour working day, i.e. approximately 5 minutes per determination. It is doubtful whether chemical methods would enable even the complete analysis of one sample to be made in a day by a single analyst.

The sensitivity of detection and the estimated precision of determination for quantities in the middle of the range of detection have been given in Table I. Excluding the alkali metals, most of the impurities could be determined more accurately by chemical methods, and certainly chemical procedures would enable much lower limits to be reached (e.g. Ref. 4). Such chemical accuracy and sensitivity is possible only in the research laboratory; for factory control, the sensitivity of the spectrochemical method is at present adequate and the precision attainable considerably better than would be expected of routine chemical analysts. The limit of detection in the spectrochemical method is imposed largely by impurities present in the electrodes and base mixture and by air-borne and other contamination; in this respect spectrochemical analysis is similar to other methods of trace determination. There is no doubt that under research conditions the determination of even smaller traces of impurities can be carried out by the method given in this paper.

Other than its speed, the greatest advantage of the spectrograph as an analytical tool is its routine reliability. It is difficult to express this on a quantitative basis, but in the present instance it can be illustrated by a comparison of routine chemical and spectrographic figures obtained over a period of time. At the beginning of the development of the spectrochemical method differences in results were usually ascribed to the spectrograph and the analysis technique altered and improved accordingly. At the present time, however, if any difference in results is obtained the chemical result is always checked first and it is usually found to be at fault. The spectrograph has in fact shown up several unsuspected errors in chemical technique or method.

The method of carrier-distillation used for the analysis of tungsten has been applied with slight modification to the examination of molybdenum. It should also be directly applicable to the very similar cases of zirconium, titanium and tantalum. In fact, the carrier distillation method as used for tungsten can confidently be recommended for the determination of trace impurities in any metal which forms a suitable refractory carbide.

Acknowledgments

The authors wish to thank Mr. R. Oldfield for making many of the measurements and Mr. van Moll and the directors of Philips Electrical Limited for permission to publish this paper.

Symposium on Analytical Chemistry

DETAILS are now available of the papers to be presented at the Symposium on Analytical Chemistry which has been arranged by the Midland Society for Analytical Chemistry and will be held at Birmingham University on September 11th and 12th, 1952. The sessions will extend from 9-30 a.m. to 4-30 p.m. each day and the papers to be discussed will be as follows :—

Thursday, September 11th.

Some Factors Influencing the Solubility of Amine Sulphates. By M. KAPEL (Birmingham University).

Rate Control of Electrode Reactions in Analytical Chemistry. By J. E. B. RANDLES (Birmingham University).

Use of Polarisation Curves in the Study of Some Electrochemical Methods of Analysis. By R. GAUGUIN (Paris).

Qualitative Analysis with Oscillographic Polarography. By J. Heyrovsky (Prague).

High Frequency Titrations (Oscillometry). By P. W. WEST (Louisiana State College).

Solid Phase Nucleation and Analytical Chemistry. By R. A. JOHNSON (Illinois University).

X-ray and Electron Microscopic Examination of Potassium Cobaltinitrite Precipitates. By J. W. ROBINSON (Birmingham University).

Friday, September 12th.

A Study of Three Suggested Reagents for the Detection of Potassium. By R. J. WINTERTON (Coventry Technical College).

Some New Applications of Fluorescence Reactions with Morin. By Fritz Feigl (Rio de Janeiro).

A New Reagent for the Precipitation of Sulphate. By D. GIBBONS (Birmingham University).

The Sensitivity of Analytical Reactions and Some New Organic Reagents. J. GILLIS (Ghent University).

Some Observations on the Direct Determination of Oxygen in Organic Compounds. By J. UNTERZAUCHER (Leverkusen).

A New Titrimetric Reagent for the Determination of Water. By T. S. WEST (Birmingham University).

The Enhancing of the Reducing Power of Mercury in the Presence of Thiocyanate and Cyanide—Its Analytical Applications. By F. BURRIEL-MARTI (Madrid University).

Developments in Spectrochemical Methods. By R. L. MITCHELL (Macaulay Institute).

Electrochemical Methods of Gas Analysis. By P. HERSCH (Mond Nickel Co.).

At 5-15 p.m. on September 11th, there will be a Civic Reception by the Lord Mayor of Birmingham, followed by a Symposium Dinner at 7-30 p.m. The registration fee of 10s. is payable to the Secretary, W. T. Edwards, 100, Rymond Road, Birmingham, 8, from whom tickets for the Symposium Dinner (11s.) may also be obtained. Mr. Edwards will also be able to make hotel reservations, the cost of room and breakfast being 30s. and 20s. in Grade I and II hotels, respectively.

A NEW leaflet on Vitreosil Hydrogen Discharge Lamps has been issued recently by The Thermal Syndicate, Ltd., Wallsend. These lamps, which have been on sale for some time, provide a source of continuous ultra-violet radiation for use in spectrometer investigations. There are a number of other applications, one of the most recent being their use in reflecting microscopy.

The Photometric Determination of Arsenic and Antimony in Tin

By W. C. Coppins, M.Sc., A.R.I.C., and J. W. Price, Ph.D., F.R.I.C.
Tin Research Institute, Greenford, Middlesex

A photometric method of determining arsenic and antimony in tin is described which obviates the necessity of working with large samples. A preliminary separation is necessary in the case of both elements, after which the molybdenum blue method is used for arsenic whilst the antimony is determined by the iodo-antimonite complex.

THE chemical determination of arsenic and antimony in tin presents no special difficulty apart from the necessity of working with large samples, and a satisfactory procedure using a sample weight of 100 g. has recently been described.[1] Photometric methods are attractive in that small samples (5 g. or less) are sufficient and can produce results of good accuracy provided a suitable measuring instrument is available. A Spekker Absorptiometer fitted with a tungsten lamp was used in the methods described below.

A preliminary separation is necessary in the case of both these elements. For example, Silverman[2] precipitated metallic arsenic by boiling with sodium hypophosphite and used the turbidity produced for colorimetric comparison, but the method is not very satisfactory and arsenic contents under 0·01% are not detected. Arsenic may also be co-precipitated with hydrated MnO_2 using fluoride to prevent precipitation of tin.[3]

Both arsenic and antimony can be separated from tin by distillation as the trichlorides[4] but a special apparatus is necessary. Distillation of arsenic alone is readily achieved using conventional types of distillation apparatus and a satisfactory procedure is given by the A.S.T.M.[5] Antimony may be separated from a hydrochloric acid solution of tin by the Reinsch reaction in which the antimony is deposited as Cu_2Sb on copper foil,[6] and it was considered that this procedure might conveniently be applied to the solution remaining after distillation of the arsenic.

For the amounts of arsenic usually found in tin ingots, the A.S.T.M. distillation method is satisfactory. The distillate is diluted to a known volume and an aliquot taken; the hydrochloric acid in the aliquot is then neutralised with ammonia and the molybdenum blue method applied. However, in the case of samples containing smaller amounts of arsenic, requiring the use of the whole of the distillate, the amount of ammonium salts introduced by neutralising the solution would interfere by preventing complete development of the blue colour. In this case preliminary removal of at least some of the hydrochloric acid is necessary and the A.S.T.M. method suggests boiling down to approx. 10 ml. A footnote emphasises that there is no loss of arsenic if the solution is kept covered during the process. Working with quantities of arsenic in the range 0·02–0·10 mg. the present authors have been unable to confirm this, in fact even careful evaporation on a water bath led to the loss of 40% of the arsenic. This loss can be prevented by adding excess nitric acid before evaporating,[7] but the nitric acid must be completely removed and it is necessary to evaporate to dryness and heat the residue at 120° C. for 1 hour. A quicker method is to add a little iron and precipitate as hydroxide with ammonia. The arsenic is completely co-precipitated and, after redissolving in a controlled amount of acid, may be determined as molybdenum blue. The presence of iron causes the final solution to be coloured green instead of blue, since iron alone gives a brownish-yellow colour under the same conditions. However, the colour due to the iron absorbs very little light if a red filter is used and after deducting a blank (which is necessary in any case) there is no difference in the photometer readings.

The molybdenum blue colour shows maximum absorption in the infra-red at 840 mμ[8], but any wave-length above 600 mμ may be used: the combination of Calorex plus Ilford 608 filters which transmits in the region of 650 mμ is suitable. The sensitivity can be increased by a factor of 1·6 by using Ilford 207 (infra-red) filters which transmit above 750 mμ. These cannot be used in conjunction with Calorex filters as the latter are infra-red absorbers, but with careful use they appear to suffer no damage.

Preliminary removal of arsenic before separating antimony by the Reinsch method is an advantage, since Cu_3As_2 will also deposit on the copper foil and cause weakening of the antimony film. Some bismuth is also deposited and this is removed as sulphide from the alkaline solution obtained by stripping the film with sodium peroxide. The antimony is finally determined as the iodo-antimonite complex[9, 10] which shows an absorption maximum at 425 mμ. Calorex plus Ilford 601 filters (max. transmission 430 mμ) have been found satisfactory. Apparently there is another larger absorption maximum in the ultra-violet and this might be used to increase the sensitivity of the method.

The Method in Detail

REAGENTS

(1) *Ferric Chloride Solution:* 1·6 g. $FeCl_3 \cdot 6H_2O$ per litre = 1 mg. Fe/ml.

(2) *Acid Molybdate Solution:* 20 g. ammonium molybdate and 285 ml. conc. sulphuric acid per litre.

(3) *Hydrazine Sulphate:* 0·15% w/v.

(4) *Potassium Iodide - Hypophosphite Solution:*

1. "Sampling and Analysis of Tin Ingots," Tin Research Institute, 1951.
2. Silverman, L., *Iron Age*, 1949, **164**, 96.
3. Yu-Lin Yao and Pe-Nien Yu, *Science Record*, 1949, **2**, 377.
4. Scherrer, J. A., *J. Res. Nat. Bur. Stand.*, 1936, **16**, 253.
5. "A.S.T.M. Methods of Chemical Analysis of Metals," 1950.
6. Clarke, S. G., *Analyst*, 1928, **53**, 373.
7. Rodden, C. J., *J. Res. Nat. Bur. Stand.*, 1940, **24**, 7.
8. Boltz, D. F. and Mellon, M. G., *Anal. Chem.*, 1947, **19**, 873.
9. McChesney, E. W., *Ind. Eng. Chem.* (Anal.), 1946, **18**, 146.
10. Holler, A. C., *Anal. Chem.*, 1947, **19**, 353.

Dissolve 100 g. potassium iodide and 20 g. sodium hypophosphite in 100 ml. water. This reagent should be freshly prepared.

APPARATUS

This consists of a 250-ml. flask fitted with a Claisen-type connector and delivery tube. The connector is fitted with a tap-funnel and a thermometer, and the delivery tube dips into a large test tube. The whole apparatus is preferably assembled from glassware with standard ground joints.

PROCEDURE

(a) *Arsenic*

Dissolve a 5 g. sample by heating with 25 ml. concentrated sulphuric acid and boil to expel free sulphur. Cool, add 15 ml. water and cool again. Pour into the flask, add 10 g. sodium chloride and 1 g. ferrous sulphate and wash in with 50 ml. concentrated hydrochloric acid. Insert the connector into the top of the flask and place 25 ml. water plus 1 ml. nitric acid in the test tube, which should be cooled in a beaker of water. Place a plug of glass wool, previously washed with hot hydrochloric acid, in the side arm of the connector to prevent traces of tin from passing over with the spray. Boil briskly until the thermometer registers 105°C. (about 10 minutes). Pour the contents of the test tube into a beaker and add 5 ml. ferric chloride solution. Make alkaline with ammonia, heat to boiling and allow to settle on the hot plate for 5–10 minutes. Filter and wash with hot water. Discard the filtrate. To the precipitate add 5 ml. acid molybdate solution drop by drop from a pipette, so that the whole precipitate is dissolved, and wash through with warm water. Transfer the extract to a 50 ml. graduated flask, add 7 ml. hydrazine sulphate solution and place in a bath of boiling water for 10 minutes. Cool, dilute to volume and measure the absorption using Calorex plus Ilford 608 filters. The 4 cm. cell gives a range of approximately 0·0002–0·002% As and the 1 cm. cell up to 0·01%. If the amount of arsenic is less than 0·05 mg. it is better to use Ilford 207 filters, in which case arsenic contents down to 0·0001% can be measured. The colour is stable for several hours.

(b) *Antimony*

Transfer the solution remaining from the arsenic distillation to a larger flask (700 ml.) containing 10 g. oxalic acid and dilute with 350 ml. water. Heat to boiling, add 1 g. sodium hypophosphite and insert a coil of electrolytic copper foil measuring 20 × 2·5 cm. The latter may conveniently be attached to the end of a glass rod and should be cleaned before use by immersing in 1 : 1 nitric and then washing with water. Place a reflux condenser in the top of the flask and boil for 2 hours. Remove the coil and wash by immersing rapidly in a beaker of freshly boiled water (the antimony film is appreciably soluble in water which contains dissolved oxygen[11]). Then, without delay, place in a small beaker and cover with water. Add 1 g. sodium peroxide, stand for about 5 mins. and warm until the coil is darkened with a layer of oxide. Remove and wash with water. Boil for 10 minutes to decompose hydrogen peroxide, cool and pass hydrogen sulphide for a few minutes. Allow to stand on the hot plate for about 10 minutes to coagulate, then filter (Whatman 540) and wash lightly with dilute ammonium nitrate solution. Neutralise the filtrate with 1 : 1 sulphuric acid and add 5 ml. excess. Evaporate to fumes, adding a few drops of nitric acid during the latter part of the evaporation to prevent volatilisation of antimony due to traces of chlorides. Cool, add a little water and heat to fumes a second time to ensure removal of nitric acid. Take up with about 20 ml. water and transfer to a 50 ml. graduated flask. Add 10 ml. potassium iodide-hypophosphite solution and dilute to the mark. Measure the absorption in a 4 cm. or 2 cm. cell using Calorex plus Ilford 601 filters. The colour is stable for 24 hours. Using a 5 g. sample this gives a range of approximately 0·0005–0·02%.

Using the above method it was found that, even after 2 hours boiling, a small amount of antimony is liable to remain in the solution (up to 0·04 mg.). For most purposes this may be neglected, but for precise results it is necessary to insert a second coil and boil for a further half-hour.

If the amount of antimony is 1 mg. or more, a heavy deposit is obtained on the coil at an early stage and it is best to remove the coil after the first 30 minutes, insert a second coil, and boil for another 2 hours. If the approximate antimony content is known, however, the sample weight should be adjusted to contain not more than 1 mg. antimony.

CALIBRATION

(a) *Arsenic*

Dissolve 0·132 g. As_2O_3 in a little caustic soda solution, acidify with hydrochloric acid and dilute to 1 litre. 1 ml. = 0·1 mg. As. From this prepare another solution containing 0·01 mg. As per ml. To calibrate for the 4 cm. cell, use varying amounts up to 0·10 mg. As (0·06 mg. if using the 207 filters) and for the 1 cm. cell up to 0·5 mg. To each aliquot add 5 ml. ferric chloride solution, oxidise with a few drops of permanganate solution and make alkaline with ammonia. Filter, redissolve and develop the molybdenum-blue colour as already described.

(b) *Antimony*

Dissolve 0·100 g. metallic antimony in 20 ml. concentrated sulphuric acid and dilute to 100 ml. 1 ml. = 1·0 mg. Sb. From this prepare a second solution, also in 20% sulphuric acid, containing 0·10 mg. Sb per ml. Measure aliquots containing up to 0·75 mg. Sb and sufficient sulphuric acid to make a total volume of 2·5 ml. of acid in each. Transfer to 50 ml. graduated flasks, add 10 ml. potassium iodide-hypophosphite solution and dilute to volume. Measure the absorption in the 4 cm. cell. The 2 cm. cell may be calibrated for amounts up to 1·5 mg. The use of a 1 cm. cell for larger amounts is not recommended owing to the uncertainty of the copper coil separation of the antimony with these amounts.

Results

The combined arsenic-antimony method was carried out on the five N.B.S. spectrograph standards and on a sample of very high purity tin of known composition (sample S). Some arsenic results obtained by evaporating

Sample	Weight used	Present		Found			
		% As	% Sb	% As Pptn. method	% As Evap. method	% Sb 1 coil	% Sb 2 coils
NBS 431	0·25 g.	0·16	0·19	0·13, 0·12	0·12	0·17	0·19
NBS 432	0·4 g.	0·075	0·095	0·068, 0·068	0·069	0·083	0·088
NBS 433	1·0 g.	0·047	0·050	0·049	0·041	0·046	0·050
NBS 434	2·0 g.	0·019	0·019	0·016	0·020	0·017	0·019
NBS 435	2·0 g.	0·009	0·010	0·009, 0·010	0·010	0·007	0·008
S	5·0 g.	0·0002	0·001	0·0003	—	0·0008	0·0008

11. Clarke, S. G., *Analyst*, 1929, **54**, 99.

the dried residue was taken up with 10 ml. of 10% hydrochloric acid (v/v), 5 ml. 0·53% ammonium molybdate and 2 ml. 0·1% hydrazine sulphate added and the colour developed in boiling water for 10 minutes as in the method already described. The figures for antimony show the results obtained by boiling with a single copper coil for 2 hours and also those obtained by the distillate with nitric acid are also given. In this case boiling for another half hour with a second coil.

Acknowledgments

This work was carried out in the laboratories of the Tin Research Institute and the authors are indebted to the International Tin Research and Development Council for permission to publish.

Research on the Constitution of Alloys

Significant Gaps in Current Work

SEVERAL significant gaps in current research on alloy constitutions are commented on in a statement by B.I.S.R.A.'s Constitution of Alloys Group (Chairman: Professor G. V. Raynor). The Group also indicates some ways in which it is willing to help fill the gaps.

In calling attention to these possible lines of research, the Group emphasises its desire to encourage new and existing work on the subject of the constitution of alloys. It is prepared to suggest systems requiring investigation and to put enquirers in touch with other workers in the same or similar fields. In particular cases, where the results of such work are likely to be of direct interest to the iron and steel industry, the Group is able to make recommendations for some financial assistance. The Group would also be glad to know of existing equilibrium diagram work which has not been reported to them, and of projected research programmes involving the constitution of alloys. Those interested should communicate with the Secretary, Constitution of Alloys Group, British Iron and Steel Research Association, 11, Park Lane, London, W.1.

The gaps in research work that the Group's reviews have indicated can be summarised as follows :—

(i) Although there appears to be no obvious gap in research work on high-temperature materials, a greater effort might well be expended in this field, owing to the relatively slow rate of progress dictated by the difficulties. In particular, more work is needed on the higher melting point alloys of Groups V and VI. Concerning materials to resist wear and high temperatures, it is felt that much more information is required on systems containing borides, and that equilibrium relations in ferrous alloys containing silicides are probably equally in need of study.

(ii) There is a surprising lack of research in the general field of ferrous alloys, except in so far as the constitution of several alloy systems involving phases with the structure of the Fe-Cr sigma phase are being adequately studied. It is felt that certain systematic work in the binary alloys of iron, would be of value, both from the theoretical point of view and to serve as a basis for studies of the complex equilibria involved in ternary and quaternary alloys. Further, the relationships between the various carbides present in alloy steels offers a wide field.

(iii) The constitution of magnesium alloys appears to be receiving little attention, and in view of the importance of these materials to aeronautical engineering, a more concentrated study may be necessary, particularly with regard to ternary and more complex alloys. Response to heat treatment of magnesium alloys is, in general, not good, and constitutional work on this subject would be of value.

(iv) The constitutional background required for the proper development of materials of the high tensile brass type and the complex bronzes is still obscure.

(v) On the theoretical side, it appears to the Group that the contributions made by those interested in the determination of the crystal structures of intermetallic phases and in accurate lattice spacing measurements are of much importance, and that greater effort in this field would not be inappropriate. Further problems connected with the theory of metals and alloys arise in the purely physical field (e.g., X-ray emission and absorption experiments on alloys, magnetic properties, low temperature specific heats) and a more intimate contact between the physicist and the metallurgist interested in the general theory of alloys would be an advantage.

It should be noted that in this statement no attempt is made to review the present position with regard to all types of alloy. No mention has been made of cases in which the Group felt that the research effort was reasonable, having regard to the various problems involved. There is no implication that subjects and systems not mentioned are of lesser interest.

Acheson Expansion

ACHESON INDUSTRIES INCORPORATED, of America, which operates Acheson Colloids, Ltd. (whose Devon works were established at Plymouth in 1911), Acheson Colloids Company of Port Huron, Michigan and Gredag Incorporated of Niagiara Falls, has recently acquired Peerless Printing Ink Company and the Synthetic Lacquer and Varnish Company, both of Philadelphia.

The Acheson organisation has been making important contributions to the plastics industry in the form of colourants dispersed in the plasticisers. This dispersion technique will now be available for the production, at Peerless, of concentrated colours for the printing ink industry.

BRITISH FLINT AND CERIUM MANUFACTURERS LTD., have moved from their temporary address at 1, Albemarle Street, London, W.1, to permanent and more commodious premises at 8, Spring Gardens, Trafalgar Square, London, W.1. The telephone number is WHItehall 1357; cable address "Ceride, London," and telegraphic address "Ceride Parl London." These offices will deal exclusively with the export and sales side of the business, the registered office and works remaining at Tonbridge, Kent.

A New Solution for the Electrolytic Polishing of Copper and Copper-Base Alloys, Particularly Tin Bronze*

By E. C. W. Perryman, M.A., A.I.M.†

(*Communication from the British Non-Ferrous Metals Research Association*)

The addition of concentrated sulphuric acid to the orthophosphoric acid solution normally used for the electrolytic polishing of copper and its alloys enables satisfactory results to be obtained in polishing tin bronzes. The solution also has advantages for the polishing of tin-free copper alloys.

THE most usual electrolyte for the electrolytic polishing of copper-base alloys is 67% orthophosphoric acid. This solution, while giving excellent results for copper and the majority of its alloys, is of no use for polishing tin bronzes. When the polishing of tin bronzes in this solution is attempted, the surface becomes covered with a black film, which is never removed in polishing. The surface is very heavily etched. It was thought that this black film might be stannous phosphate, which is insoluble in orthophosphoric acid but soluble in mineral acids. An addition of concentrated sulphuric acid was therefore made to the phosphoric acid bath in the hope that the stannous phosphate would be dissolved and polishing would result.

Experimental Details

Two solutions were finally adopted: (1) 67% orthophosphoric acid, 10% conc. sulphuric acid and 23% distilled water for copper and its alloys, including tin bronzes up to 6% tin; and (2) 47% orthophosphoric acid, 20% conc. sulphuric acid and 33% distilled water for 9% tin bronzes. The circuit diagram is shown in Fig. 1 together with the electrolytic polishing cell, which consisted of a copper cathode placed about 2 cm. above the specimen surface. The polishing conditions were the same for both solutions, namely 2–2·2V. and a current density of 0·1 amp./sq.cm. The time of polishing depended upon the state of the initial surface, but starting from a surface which had been roughly polished with metal polish, 15 minutes was generally found sufficient. To etch the specimen after polishing, the voltage was reduced to 0·8 volt for approximately 30 seconds; the exact time of etching, however, depended upon the metal or alloy being etched. An alternative method of etching was to short circuit the electrodes for approximately 30 seconds. The new solution had one advantage over the normal 67% orthophosphoric acid solution in that the washing of the specimen after

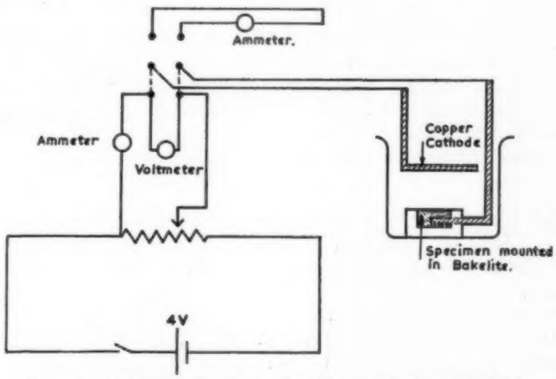

Fig. 1.—Circuit diagram for electrolytic polishing.

* *B.N.F.M.R.A. Tech. Memo* 80 P.
† Formerly Investigator, B.N.F.M.R.A., London. Now with Aluminium Laboratories, Ltd., Kingston, Ontario, Canada.

Fig. 2.—As-cast 6% tin bronze. × 250

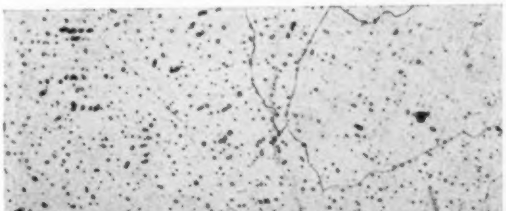

Fig. 3.—As-cast 3% tin bronze. × 50

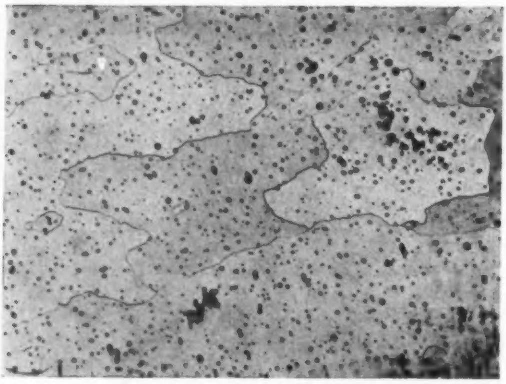

Fig. 4.—As-cast 6% tin bronze annealed at 625° C. for 4 hours. × 50

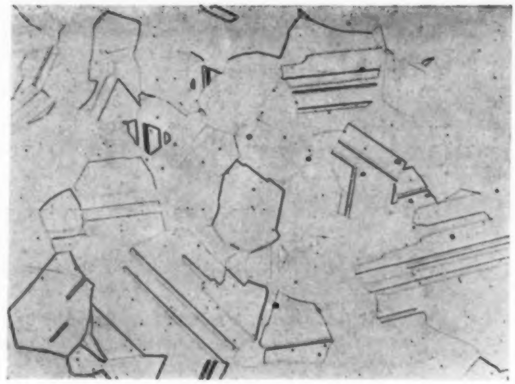

Fig. 5.—6% tin bronze rolled and annealed. × 100

polishing was not so critical. When polishing with 67% orthophosphoric acid a viscous film is formed on the specimen surface which can only be removed if the specimen is washed with a very strong jet of water; no such precautions were necessary with the solution containing sulphuric acid.

Results

(a) Copper and Copper-Base Alloys—Including Binary Copper-Tin Alloys up to 6% Tin.

An excellent polish was obtained on copper, brasses and binary copper-tin alloys containing up to 6% tin, using the solution containing 67% orthophosphoric acid, 10% conc. sulphuric acid and 23% distilled water, and moreover the polish obtained on copper and brasses was equal to that obtained using the normal 67% orthophosphoric acid solution. As with all other electrolytic polishing techniques, the polish obtained on homogeneous materials was superior to that obtained on heterogeneous materials. Figs. 2 and 3 show the structures of vacuum-cast 6% and 3% tin bronzes respectively. It will be seen from Fig. 2 that the structure is very heterogeneous as a result of coring and, moreover, the difference in tin content between the different areas is sufficient to prevent almost completely the polishing of the tin-rich areas. This is presumably due to the solid solution becoming more cathodic as the tin content increases. This is supported by the fact that, with the 3% tin bronze, the relief between the cored areas was by no means as large (see Fig. 3). In one of the tin-rich areas in Fig. 2 will be seen a small amount of the $\alpha + \delta$ eutectoid. Fig. 4 shows a vacuum cast 6% tin bronze which has been annealed at 625° C. for 4 hours and water quenched. The black spots in Figs. 2–4 are due to porosity in the castings. Fig. 5 shows the grain structure of a 6% tin bronze which was cold rolled and annealed at 625° C. for 4 hours.

(b) Binary Copper–9%Tin Alloys.

When the polishing of these alloys was attempted in the solution containing 67% orthophosphoric acid, 10% conc. sulphuric acid and 23% distilled water, a black film was formed as was obtained with the lower tin alloys in 67% orthophosphoric acid. This black film did not completely cover the surface, the remaining parts being satisfactorily polished. To overcome this, the solution containing 47% orthophosphoric acid, 20% conc. sulphuric acid and 33% distilled water was used. With this solution no black film was formed although there was a tendency for the surface to become pitted. While the polish was not very good for low power examination it was suitable for higher power work.

(c) Copper-Tin Alloys Containing 0·4% Phosphorus

Bronzes containing 0·4% phosphorus behaved quite differently from phosphorus-free alloys. After polishing

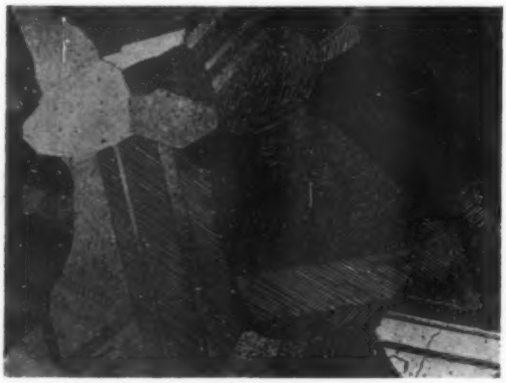

Fig. 6.—6% tin bronze containing 0·4% phosphorus rolled and annealed. × 200

Fig. 7.—Same specimen as Fig. 6, after immersing specimen in polishing solution and brushing with camel-hair brush. Polarised light. × 100

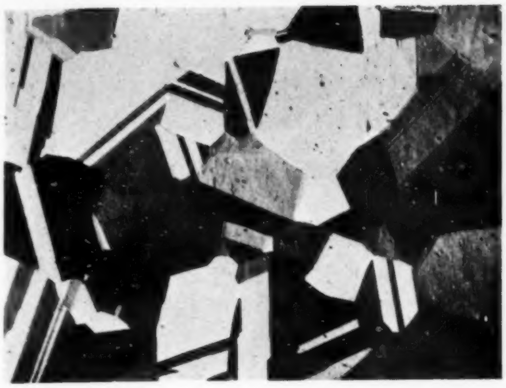

Fig. 8.—3% tin bronze containing 0·4% phosphorus rolled and annealed. Polarised light. × 100

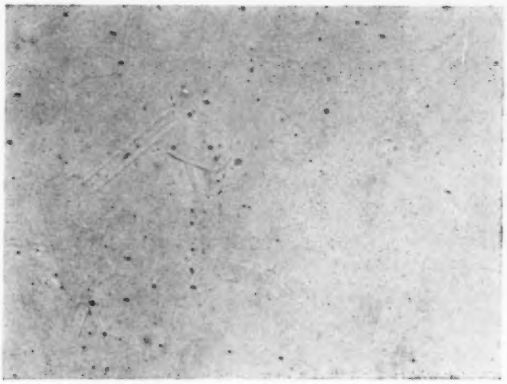

Fig. 9.—Same field as Fig. 8—normal illumination. × 100

a 6% tin bronze containing 0·4% phosphorus in the solution containing 67% orthophosphoric acid, 10% conc. sulphuric acid and 23% distilled water, the surface, after drying, appeared to be heavily etched. On microscopical examination, besides the grain structure being apparent, striations, which appeared to bear some relationship with the crystallographic structure, were also to be seen (Fig. 6). Examination under polarised light showed that this surface was optically active. By immersing the specimen in the polishing solution and rubbing the surface carefully with a camel-hair brush, the etched appearance and the striations disappeared, leaving a polished surface which, however, was still optically active (Fig. 7). Similar striations have been observed by Hone and Pearson[1] on aluminium after anodising an electrolytically polished surface and were found to be formed when the oxide film exceeded a certain thickness. On polishing a 3% tin bronze containing 0·4% phosphorus, although the polished surface did not show either the etched appearance or the striations after drying as did the 6% tin bronze containing 0·4% phosphorus, the polished surface was optically active (Figs. 8 and 9). It thus appears that, during the electrolytic polishing of bronzes containing 0·4% phosphorus, an anodic optically active film is formed which increases in thickness as the tin and phosphorus contents increase.

The tendency for these optically active surfaces to be formed was found to decrease as the polishing solution became more concentrated in copper ions.

Hone and Pearson[1] have shown that there is a close relationship between the orientation of the substrate metal and the optical characteristics of the film, and Woodard[2] has used this technique for studying the plastic deformation of Monel metal. Barrett and Levenson[3] have shown that, during plastic deformation, areas of non-uniform orientation are produced within individual grains. If, therefore, a plastically deformed specimen is examined by the above mentioned technique, instead of each grain being of uniform intensity as with annealed material (Figs. 7 and 8), the light intensity will vary within an individual grain. Such effects have been found on examining plastically deformed tin bronze (Fig. 10). It is worth noting the clarity with which the deformation bands are revealed by polarised light (*cf* Fig. 11).

Acknowledgments

The author thanks the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this work.

1 Hone, A. and Pearson, E. C., *Metal Progress*, 1948, **53**, 363–366.
2 Woodard, D. H., *Journ. of Metals*, 1949, **1**, 722.
3 Barrett, C. S. and Levenson, L. H., *Trans. Amer. Inst. Min. Met. Eng.*, 1940, **137**, 112.

Fig. 10.—Plastically deformed 6% tin bronze containing 0.4% phosphorus. Polarised light. × 75

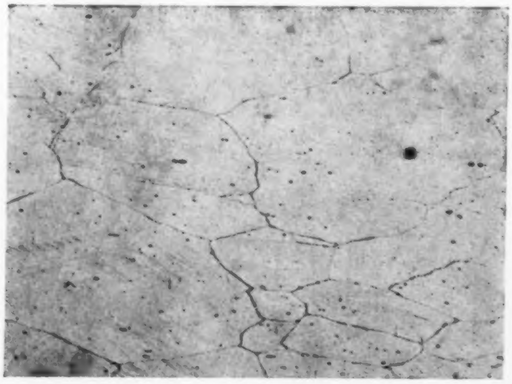

Fig. 11.—Same field as Fig. 10—normal illumination. ×75

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